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WAYS OF LIVING

EDITED BY

J. Arthur Thomson, M.A., LL.D.

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WAYS OF LIVING
NATURE AND MAN

EDITED BY

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University of Aberdeen

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— B —
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GENERAL INTRODUCTION

Of all human ambitions an open mind eagerly expectant of new discoveries and ready to remold convictions in the light of added knowledge and dispelled ignorances and misapprehensions, is the noblest, the rarest and the most difficult to achieve.

JAMES HARVEY ROBINSON, in *"The Humanizing of Knowledge."*

It is the purpose of DORAN'S MODERN READERS' BOOKSHELF to bring together in brief, stimulating form a group of books that will be fresh appraisals of many things that interest modern men and women. Much of History, Literature, Biography and Science is of intense fascination for readers to-day and is lost to them by reason of being surrounded by a forbidding and meticulous scholarship.

These books are designed to be simple, short, authoritative, and such as would arouse the interest of intelligent readers. As nearly as possible they will be intended, in Professor Robin-

son's words quoted above, "to remold convictions in the light of added knowledge."

This "adding of knowledge" and a widespread eagerness for it are two of the chief characteristics of our time. Never before, probably, has there been so great a desire to know, or so many exciting discoveries of truth of one sort or another. Knowledge and the quest for it has now about it the glamour of an adventure. To the quickening of this spirit in our day DORAN'S MODERN READERS' BOOKSHELF hopes to contribute.

In addition to the volumes announced here others are in preparation for early publication. The Editors will welcome suggestions for the BOOKSHELF and will be glad to consider any manuscripts suitable for inclusion.

THE EDITORS.

PREFACE

THIS book had its origin in the request of the Aberdeen branch of the Workers' Educational Association that they should be instructed in the Ways of Life that are exhibited by plants and animals, the idea being that these might afford some useful suggestions to thoughtful men. Thus it came about that five of us gave lectures which are now published more or less as they were delivered. They deal with the three chief ways of life—the individualist or independent, the parasitic, and the co-operative or social. The treatment has varied in the different chapters, but this diversity has its educative value; and the necessarily illustrative selection of material is also of use, since it does not over-weigh the presentation of a somewhat novel point of view. No contributor is responsible for what the others have said; but we are all indebted to Professor Geddes for his kindness in

undertaking the difficult task of writing a synthetic Envoy.

J. ARTHUR THOMSON,
JOHN RENNIE,
MAC GREGOR SKENE,
A. S. WATT,
ROBERT D. LOCKHART.

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Each for Himself

BY J. ARTHUR THOMSON, M.A., LL.D.,
Professor of Natural History in the University of Aberdeen.

WAYS OF LIVING

Chapter I

Each for Himself

THE VARIETY OF NATURE'S WAYS

THE world of life is so varied that we find in it the parallels or prototypes, the anticipations and exaggerations, of most of the ways of men. An ant-hill is in many respects like a crowded city; the fox lives like a solitary outlaw for most of the year. The wild horses are restless nomads roaming in search of pasture; the rock-barnacles and oysters are extreme in their sedentariness, after the early free-swimming days are past. Many organisms live in partnership with others—sometimes external commensals as in the hermit-crab and sea-anemone "Mutual Benefit Society," sometimes intimate symbions as in the case of lichens, which are dual plants, made up of Alga and Fungus living in close

alliance. A worker-bee passes through a sequence of services within the hive, being promoted, as Rösch has shown, from duty to duty before she is allowed to pass into the open-air world of sunshine and flowers. What a contrast this kind of self-subordinating life to that of the vast majority of insects, which fend for themselves alone from the time they get their wings, or even earlier. There are predatory animals like the wolves, that live in pairs through most of the summer and join in packs in the winter. There are great grazing herds of cud-chewers, which may include numerous distinct family-groups, yet show very little in the way of competition among themselves. Do they not share the pasture amicably as long as it lasts? What a contrast this to the snarling of the hyænas crowded around the carcase, or the jostling seen in many a shoal of fishes, where there is competition for every mouthful.

Our impression of the diversity of Nature's ways grows strong when we think of the many different habitats discovered by insurgent organisms by land and sea; the many kinds of diet (including those adopted by parasites); the va-

riety of reaction to the seasons, as in migration and hibernation; the extraordinary, as if experimental, heterogeneity of sex-relations—promiscuity, polygamy, polyandry, monogamy, and more besides; all the ways of multiplying and of caring for progeny, if care be needed; the four or five different kinds of families; the graded series of animal aggregates and integrates, communities and societies; the incipient indications of property, capital, and permanent products; the linking together of apparently remote lives, such as mistletoe and missel-thrush, and the changes of habits that have been associated with changes of the world-stage, both as regards surface-relief and climate, from one geological period to another. But we need not linger over the broad fact that the ways of living illustrated in Animate Nature are very diverse and show many quaint and suggestive parallelisms with Man's. To illustrate this is the general purpose of this little book; and our business in this chapter is to concentrate attention on individualistic policy.

NO CREATURE ISOLATED

In the strict sense no creature ever lives or dies quite to itself. Green plants are more independent than ordinary animals, for they are able in the sunlight to build up complex foodstuffs from the beggarly elements of the air and the soil-water. This secret of photo-synthesis makes green plants in an almost unique way self-supporting, whereas animals depend for food on other animals and ultimately on plants. Yet even the green plants are "retainers to other parts of Nature," to use John Locke's fine phrase. The flowering-plant requires the bee or the butterfly for its pollination, and the bird for its seed-scattering. Similarly, even the most individualistic and apparently self-sufficient animal may require helpful bacteria, yeast-plants, Infusorians, or other microbes, in its food-canal to assist in the fundamentally important process of digestion. No organism achieves isolated success; Animate Nature is a web of inter-relations. But having made our bow to one of the grandest of commonplaces, we are free to come nearer our particular theme—the "each for himself"

mode of life. There is only one other fence to cross.

EGOISM AND ALTRUISM

It must not be thought that the contrast between the individualistic animals and the co-operative, the solitary and the social, is the same as the contrast between egoistic and altruistic types, between the selfish and the other-regarding. That is not the point: our contrast is between different policies or ways of living, not between dispositions or temperaments. The individualistic otter, living and hunting alone, is a most excellent mother, not only nurturing but educating her cubs; she is not less altruistic, if the word may be used for animals, than the co-operative beaver. The pair of golden eagles in their lonely retreat are as devoted parents as the rooks in the crowded rookery. The foxes hunt and live alone except during the pairing and parentage months, when the male will bring food to his delightfully playful children, and will even defend them in time of danger. The parental care of the solitary bees is not markedly inferior

to that of the social species that live in wild colonies or in domesticated hives.

It comes to this, that as many of the most pronounced individualists among animals are good mates and parents, the contrast is social rather than ethical; it is between two divergent ways of living—each for himself or each for others as well. There is good reason for agreeing with Herbert Spencer that the purely self-seeking animal is as much a fiction as the purely economic man. "Self-sacrifice," he said, "is no less primordial than self-preservation." "From the dawn of life, altruism has been no less essential than egoism." With this we are in deep agreement, especially if we may add the corollary that the streams of self-gratifying and other-regarding (egoistic and altruistic) impulses, "hunger" and "love" in wide senses, have continually influenced one another, even uniting and separating again, in the course of evolution. It is meat and drink to some animals to care for their offspring, and there are strange instances of give and take between love and hunger.

THE STRUGGLE FOR EXISTENCE

From amidst the keen competition of industrialism Darwin subconsciously projected on Animate Nature the idea of individualistic struggle. Each for himself and Natural Selection take the hindmost, that is the Law of the Jungle. But Darwin was too wise a naturalist not to see that the struggle for existence was much more than jostling and elbowing for self. It includes, as he pointed out very emphatically, the other-regarding efforts that animals so often make to secure the welfare of their offspring and give them a good send-off in life.

One of the headings in Darwin's *Origin of Species* (1859) is "Struggle for Life most severe between Individuals and Varieties of the same Species," and it cannot be doubted that there is often very intense competition among seedlings of the same kind in a crowded plot, or among the locusts in a desperately hungry swarm. The cases Darwin mentioned under the heading referred to were instances of competition between allied forms rather than between members of the same species. One species of swallow, spreading in the

United States, has caused the decrease of another species. The increase of the missel-thrush in some parts of Scotland has caused the decrease of the song-thrush. One kind of rat, of cockroach, of bee, of charlock ousts another. These were Darwin's illustrations of his point. "We can dimly see why the competition should be most severe between allied forms, which fill nearly the same place in the economy of Nature; but probably in no one case could we precisely say why one species has been victorious over another in the great battle of life." But let us leave the question open, whether the severity of competition is keenest between fellows of the same species, or foes of quite different species; we must lay emphasis on Darwin's broad view of the Struggle for Existence, for it is in this way that we shall be able to put the contrast between the individualistic and the communal, the solitary and the social, in its proper biological setting. Speaking of the "Struggle for Existence," Darwin wrote: "I should premise that I use this term in a large and metaphorical sense, including dependence of one being on another, and including (which is more important) not only the life of the indi-

vidual, but success in leaving progeny." In other words, the "Struggle for Existence" is a formula including all the reactions and endeavours that living creatures make against environing difficulties and limitations. One way out is to intensify individual effort, to tighten the belt, to set the teeth, to hustle and jostle, to strain and strive. This is the individualistic, self-sufficient answer-back, *and it certainly pays.* The other way out is to join hands, to link lives, to practise mutual aid, to subordinate self, to increase parental care and kin-sympathy. This is the co-operative answer-back, *and it certainly pays.* Thus we see clearly that the two régimes or policies or ways of life that we are seeking to contrast are not to be pitted against one another as antithetic alternatives. They are both successful solutions of the practical problems raised by environing difficulties and limitations; and *they may be combined.*

THE CONTRAST

The self-sufficient, actively individualistic policy is contrasted with the parasitic (including

saprophytic, or rottenness-eating) way of life on the one hand, and with the co-operative or communal on the other. What most deeply marks parasitism, with its many expressions (see Chapters III and IV), is the attainment of food and shelter with a minimum of individual struggle, and its frequent stigma is some degree of reduction and degeneracy. What most deeply marks the co-operative (social, communal, gregarious, or partnership) régime is some measure of self-subordination on the part of the co-operators, and some alleviation of the individual's struggle for existence. Its nemesis may be a loss of individual all-roundness and a sheltering of types that would be eliminated in individualistic conditions. The self-sufficient, actively individualistic mode of life among animals may be compared to that of a crofter, living in many cases in remarkable independence. The co-operative or communal mode of life among animals may be compared to that of urban society with its manifold division of labour. It does not seem to us to make a deep difference that man is nowadays nominally one species which includes predatory and pacific, individualist and socialist, self-sufficient and associa-

tive types, whereas when we contrast hare and rabbit, eagle and rook, ichneumon-fly and humble-bee, we are dealing with entirely different species. The point of the contrast remains, whether in one species or in different species; it is a contrast between two divergent ways of living.

The advantages of the "each for himself" mode of life are that it fosters all-roundness of development and sturdy vigour. The disadvantages are that the struggle for existence may be intensified to the unendurable uttermost—which spells extinction—that the mastery of the environment is more limited, and that there are fewer opportunities for cultivating the integrative kin-sympathies which flourish in a social *milieu*. On the other hand, the co-operative, gregarious, social mode of life, which certainly makes for stability, achievement, social sentiment, and sometimes external heritage, as in the ant-hill and the beaver-village, is apt to over-subordinate the individual and to throw a shield over variations that were sometimes better dead. It is an extraordinary fact that some ant-species, that can neither collect food nor eat it of themselves, are kept alive by their slaves! Which things are a parable.

No doubt society made man, no doubt a wholesome society favours morals and manners more than does solitary, self-sufficient life, but we cannot shut our eyes to the tax that man has to pay for his societies. There tends to be a loss of all-roundness, many-sided vigour, and independence; and there is a sheltering of undesirable variations which would not, in any case, *multiply* under the sterner sifting associated with the individualistic mode of life. In saying this we are not reactionary, for we are convinced that one of the most powerful factors in human progress is tightening and refining social inter-relations or linkages. We are simply protesting that man has something to learn from the unsocial gorilla as well as from the troop of monkeys, from the otter as well as from the wasp, from the eagle as well as from the rook. The two different policies may be, *in man's case*, combined; the virtues of both may be secured if man is wise.

PROS AND CONS

In contrasting the individualistic and the communal we must try to avoid the fallacy of pick-

ing our cases to show that one way is better than the other. It is when we take a broad survey that we become convinced of the open secret that *both ways are best*. Towards given ends, at particular times, in certain circumstances, man should learn from the eagle; towards other ends, at other times, and in other circumstances he should learn from the rook. A broad survey shows that there are virtues and defects in each way of life, which is more than can be said for thorough-going parasitism.

Let us see the contrast of little struggle and much, as two poets have seen it:

"Behold the life of ease, it drifts.
The sharpened life commands its course:
She winnows, winnows roughly, sifts,
To dip her chosen in her source.
Contention is the vital force
Whence pluck they brains, her prize of gifts."

(MEREDITH.)

"For life is not as idle ore,
But iron dug from central gloom,
And heated hot with burning fears,
And dipt in baths of hissing tears,
And battered by the shocks of doom
To shape and use."

(TENNYSON.)

If we consider the short list of British mammals, we see a striking contrast between the solitary and the social. The solitary or individualistic mode of life is illustrated by wild cat, fox, otter, badger, pine marten, stoat, weasel, hedgehog, mole, shrews, hares, squirrel, and dormouse—a very attractive set of animals. The gregarious types are deer, rabbits, rats, mice, voles, and bats. A comparison of the two lists shows at a glance that all the finer types are individualistic with the exception of the deer. But this is proving too much by confining attention to a particular type of animal, namely, mammals, and to a country in which the extension of agricultural land has greatly diminished the chances of "Wild Life" among the larger creatures. If we take a wider sweep, we see that the gregarious or communal mammals are not well represented in Britain. We have to correct the impression made by rabbits, rats, mice, voles, and bats by remembering the cleverness and loquacity of monkeys, the wisdom of elephants, the intelligence and adventurousness of wild horses, the defence of the young amongst gregarious ruminants, the kin-sympathy of the viscachas, and so on, through an

attractive list to which we shall return in Chapter VI.

Solitary, self-sufficient, or, as we are calling them, individualist animals are often very fine types, but we must not credit their mode of life with engendering all their virtues. It must often be that they are the well-endowed survivors in difficult conditions. Their fineness is not altogether due to their individualist ways. The other side of it is that they are able to stand alone, four-square to the winds, because of their original virtues of body and brain. Thus in an unfriendly country like Britain, in which the list of mammals is continually shrinking, those solitaries that survive would have been eliminated long since if they had not been endowed with many good qualities, such as alertness and resourcefulness.

Similarly, when we think of the excellences of elephants, wild horses, beavers, and wolves or of the great intelligence of parrots, cranes, and rooks, we must not hastily give all the credit to the mode of life. In the cases mentioned, though not in all others, there must have been very fine material to work with, as is plain enough when we think of the equally endowed solitary fox and

gregarious wolf, of the equally endowed solitary crow and gregarious rook.

Or, again, when we admire the great excellence of many of the social animals, we must not forget the seamy side, that the evolution of some sort of societary form or mutual aid sometimes serves as a shield which secures the survival of types that are not very intelligent, or resourceful, or parentally solicitous, or sympathetic. In not a few cases, indeed, the social animal bears a stamp of inferiority, and would perhaps have been eliminated if it had not been shielded by its sociality, using the word in a wide sense. Some gregariousness or corporate activity has been a shield helping the survival of pigmies like mice, of dull-witted creatures like bats—and so on down to the slave-keeping ants that cannot feed themselves.

We do not wish to over-labour a simple point, yet it is of importance, especially since it is the habit of propagandists to select particular cases from among animals and from among men, and hold them up as examples of the excellence or the danger of the individualistic or the socialistic mode of life. Each is a good solution, as we have

said, according to ends, times, and circumstances. Both ways are best.

ORIGIN OF THE TWO WAYS

When we consider the diverse ways of life as alternative reactions or answers-back to the struggle for existence, we can understand something of their origin. Keeping to the individualistic and the co-operative, parasitism being separately discussed, we see that the parting of the ways may be determined by habits, surroundings, or constitution.

(*a*) When an animal is a fisher or a hunter it is more likely to follow the "each for himself" policy. Much depends on the nature of the food. It is easier for the honey-sucking bees to be social than it would be for the insect-snaring or the insect-hunting spiders, though even in this individualist class the social experiment has been made.

(*b*) The environment also counts for something. There are places so inhospitable and difficult that only solitaries have much chance of surviving. The mites in a cheese can afford to be

multitudinous, but the active fresh-water mites are not gregarious. The point must not be pressed too hard; thus the social marmots live on Alpine heights where the environment is inhospitable and the fare not too generous; but on the whole the self-sufficient, solitary types are characteristic of the more strenuous surroundings.

(*c*) But besides functional and environmental factors there were doubtless constitutional and temperamental differences which gave the originators of the habit a bias in one direction or the other. Among animals, just as among men, there must be variations towards self-subordination and towards self-assertion, towards yielding and towards elbowing, towards all-round independence or towards co-operative specialisation. In some cases these constitutional or organismal biases may be correlated with variations in the ductless glands; in other cases—think of rook and crow—we have probably to do with a *psychical* dichotomy.

THE BADGER AS A PARTICULAR CASE

Up and down in many parts of England there are places whose names begin with Brock, like

Brockhampton and Brockenhurst, and they indicate, no doubt, that the brock or badger was once much commoner than it is to-day. Yet the interesting creature is holding its own not so very badly, and it may be useful to ask how such a big carnivore, nearly a yard long, manages to survive in a country which cannot be called hospitable.

Many people would give as the first reason for the badger's survival that it comes out under cover of night. Even if there is only partial darkness, the general grey colouring, with black and white in parts, makes it very inconspicuous. It can venture afield on a moonlight night, but it shows good sense in working along a dry ditch or in the shadow of a wall. Mr. Tregarthen's *Life Story of a Badger* (Murray, 1925) is at the high-water mark of field Natural History—a careful, intimate, and convincing study; and he speaks of the brock's persistence among the granite boulders of West Cornwall; "it is an ancient creature in an ancient land, where the grey of its coat blends, like that of no other animal, so harmoniously with the grey of the rock that only a practised eye can distinguish the wearer when at dawn he threads the boulder-strewn slopes or

steals over the massed crags of a cairn." The badger has as one of its hereditary gifts the cloak of invisibility, and it knows how to use it.

A second reason for the badger's survival may be found in its powers as a burrower. Its "sett" is on a big scale, perhaps a hundred yards long, and it is always being added to. The creature has prodigious muscular strength and it can get through a great deal of digging in a single night. There is believed to be a fresh excavation when a family is expected, and there are certainly "spring cleanings," though characteristic of autumn, when the old bedding is got rid of, and fresh material such as withered bracken is brought in. For the badger is certainly not a "foul" animal.

One of the characteristics of the badger's possession of the under-world is that the same place is utilised for generations. The burrows may be extended, but the badger holds fast to a good site. This is interesting, because it shows that even the badger does not live or die to itself alone.

Another feature that makes for survival is the great variety of food-stuffs that the badger can use; for an animal that can readily turn from one

edible thing to another has much more chance of holding its own than a "specialist" in diet. The badger eats beetles and grubs, wasps and wild honey, slugs and worms, fishes and frogs, roots and fruits, and many other things besides. It approaches the otter, another individualist, in the length of its bill of fare, but it is not nearly so much of a hunter. It takes what it can get, such as hen's eggs laid out of bounds or a rabbit caught in a trap.

Part of the badger's success is due to the good send-off in life that the parents secure for their offspring. The badger is a good type of the self-sufficient, solitary, individualist animal, but it is very far from being egoistic, and there is survival value in its parental care. The cubs are born in the recesses of the burrow and are blind for about a fortnight. They are transferred from one nursery to another for hygienic reasons. The father may bury them deeper if the terriers are on the scent, and he will fight for them to the death. The predatory type may be a devoted parent! The mother is very solicitous, and there is definite evidence, as in the otter, of detailed education. Badgers evidently believe in small families, for

three is the usual number in a litter. There is no infantile mortality here, though "each for himself" is, we maintain, the badger's rule in life. If our country were wilder, there would soon be more badgers, re-peopling the Brockenhursts and Brockleys; but the spreading of intensive agriculture is hard on these old-fashioned and conservative creatures.

Some naturalists speak of the badger as hibernating in very severe weather, and regard this as another factor in survival. But we think this is using the word hibernate in a loose sense. For hibernation means more than taking a long sleep when it is very cold and the metaphorical wolf is at the door; it means a definite imperfection in the warm-bloodedness, and a peculiar lapse towards reptiledom, with very remarkable constitutional changes in heart and blood, in breathing and excretion. No doubt the badger takes long sleeps, but it is not a true hibernator.

We do not emphasise the badger's strength as any considerable part of its survival secret, for strength did not save the giant deer from extermination. Nor do we attach special importance to the badger's vigilant senses of hearing and

smell, for higher qualities in these directions are seen in the wild cat, which is nevertheless a very rare mammal in Britain nowadays. But it seems justifiable to attach special importance to the badger's "safety first" policy. It is certainly no coward; it can give a good account of itself against a big dog; its bite is formidable and the grip of its jaws is as unrelaxing as that of a vice; it has very strong claws, though it does *not* sharpen them on the boles of trees. The badger is well equipped and a good fighter, yet we think its policy is to be non-aggressive. It is an individualist, but it is not a meddler. It has no appetite for living dangerously. It is good news to learn from Mr. Tregarthen that along the cliffs from St. Ives to the Land's End there are fourteen earths; from the Land's End to Newlyn, twelve—twenty-six in all, averaging about one to a mile of coast. Inland, there are as many as eighty-one earths, and few, if indeed any, of these are altogether out of use. And there are other places besides Cornwall where this ancient, slow-going, unplastic individualist is holding its own.

CONCLUSION

We have lingered over this particular instance in order to give concreteness to our study, but we might equally well have taken the otter or the stoat, the mole or the hedgehog, the eagle or the raven, the adder or the toad. And our conclusion would have been the same, that the "each for himself" mode of life (within the limits indicated) is a very effective policy in the struggle for existence, but that survival depends not so much on the mode of life as on the qualities of those that have made it their policy. From the biologist's point of view, individualism and socialism, self-sufficiency and co-operative interdependence, are both valid. Both have their advantages and disadvantages, their rewards and handicaps. But the most radically important qualities, as regards survival and progress, are *embodied in the individual*, even in man's case, where the social heritage counts for so much. There is more than a grain of truth in the cynic's lines

> "For forms of government let fools contest;
> Whate'er is best administered is best,"

and there is more still in the biological conclusion that of deeper importance than the way of life, as long as it does not mean parasitism and loss of individuality, is the toughness and fineness of the creature's protoplasm—all that is bred in the bone, imbued in the blood, and embodied in the mind.

Chapter II

Individualist Plants

By MACGREGOR SKENE, D.Sc.,
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Chapter II

Individualist Plants

IN another chapter it is made clear that plants are organisms which characteristically live in communities. Where growth conditions are favourable they cover the soil of the land surface with the thick carpet of the pasture, or the close canopy of the forest, and it is difficult to find a place where one plant may grow uninfluenced by, or without influence on, another. In desert conditions vegetation is open, and the thorny shrubs and trees are widely spaced; but even here the scattered individuals of a species of Cactus or Acacia may stamp the landscape with a uniformity of character, which proclaims the importance of the gregarious quality of plant life. If birds of a feather flock together, plants of the same, and of very different, foliage grow together. The integration of the community may fall very low, even to zero, but, from the one extreme of the desert, to the other of the tropical rain forest,

we might trace a whole series of connecting links. Communal life is the norm.

RARITY OF COMPLETE INDEPENDENCE

Perhaps only in the open surface waters of the ocean and of lakes, where a floating population of diatoms, peridines, and other minute, unicellular plants waxes and wanes with the seasons, do plants exist nearly free from mutual influence. It is not of these that we wish to write here, but rather of the individualistic features of the life of the ordinary land flowering plants which are most familiar to us. For these, though they live in communities, have a peculiar independence which makes at once possible and imperative their singular rooted immobility. More independent and less individualistic than the higher animal, the higher plant leads a life founded on a unique mode of nutrition.

NUTRITION OF PLANTS

Man has an intimate and practical knowledge of his own way of obtaining and utilising food.

But this only made more difficult the elucidation of the nutrition of the plant. The tree possesses nothing comparable to the alimentary system of a mammal, and such attempts as were made to explain the nutritive processes of the one in terms of those of the other could only be misleading. The experience of the husbandman had made it clear that the condition of the soil was of importance to the plant, and it was natural to believe that from the soil the plant absorbed all its food substance. Endeavours to arrive at a more precise understanding led to difficulties. In one of the first exact investigations on plant physiology, the famous "Brussels experiment" which was carried out by van Helmont about 1600, a willow was grown in a weighed pot of soil carefully protected from dust; after five years the weight of the willow and of the soil was determined. The soil had decreased by 2 ozs., the willow had increased by 164 lbs. It was concluded that the surplus gain in weight was due to the water which had been absorbed. This was an erroneous deduction, but no better explanation was possible until the science of chemistry had advanced far beyond the position it occupied in 1600.

The first step was taken by the great English chemist Priestley in 1774. He knew that air is constantly being vitiated by the respiration of animals, and by combustion, but that the process is not cumulative. He looked for the agent that makes the air "good" again, and he found it in the plant. He showed that if a sprig of mint was placed in a vessel of air in which a candle had burned out, or in which a mouse had been allowed to die of suffocation, the air would gradually be made "good" again, and permit once more the burning of a candle or the respiration of another mouse. The Dutch physician Ingenhousz in 1779, and the Swiss scientist de Saussure in 1804, linked up this discovery with the nutrition of the plant.

PHOTO-SYNTHESIS

Ordinary air contains a very small proportion of carbon dioxide, or carbonic acid gas. This is the gas which is formed in animal respiration, and in combustion. It is absorbed by the leaves of green plants, and with the aid of the energy of sunlight it is reduced, that is, deprived of its

oxygen, which is restored to the atmosphere. With the carbon, which never appears in the free state, and with water the plant forms organic material, sugars and starch. This building up, or synthesis, of organic matter from carbon dioxide is the fundamental process in plant nutrition.

To understand its precise significance we must look a little more closely at the process. Solid plant material, like a bit of stick, consists of organic compounds. When we burn it we convert it by oxidation into carbon dioxide and water, the substances from which the plant had constructed it. But, in the process, it gives off large quantities of energy in the form of light and heat. To change the carbon dioxide into organic material the plant must, as it were, be able to put back that energy, and this it can do by utilising the energy of light. It is able to absorb and convert this light energy by virtue of the green pigments, the chlorophyll, of its leaves. In this lies the chief function of foliage. The green leaf is an organ which is able to absorb the first raw material, carbon dioxide, from the atmosphere; it is supplied with the second raw material, water, from the soil, through the conducting channels

of root and stem; and it can absorb and transform the energy of light by its green pigments.

NITROGEN-SUPPLIES

Water and carbon dioxide are not the only material requirements of the plant. Along with the water it takes from the soil a number of mineral salts, containing such elements as nitrogen, sulphur, potassium, and calcium. Of these the most important is nitrogen. Plant and animal alike are built up of organic compounds of several classes. The chief are the carbohydrates, the oils and the proteins. The third of these contains nitrogen as an essential and characteristic constituent. The plant alone can form these substances from simple inorganic material, and the fundamental process is the synthesis of the carbohydrates with the help of light energy. Soil fertility we know to be important, and a soil is fertile when it can supply the necessary mineral constituents. But the bulk of the dry substance of the plant consists of the carbon compounds, the raw material of which is a gas of which only about three parts are present in ten thousand parts of ordinary air.

The nutrition of a green plant is thus entirely different from that of an animal. The animal feeds at a high level, using only organic compounds ready made for it by plant activities. The plant feeds at a low level, using the simple raw materials of inorganic nature. Since the animal feeds directly or indirectly on plant-products, the nutrition of plants assumes a very wide importance. Indeed the synthesis of organic matter by the green plant may be looked on as the most important of all the processes of life on the face of the earth, for on it depends the whole of the life we know. And in addition the plant supplies us with the bulk of the salts which are essential for the life of the body of man and beast.

FOLIAGE

How does this mode of nutrition affect the life of the plant? Most obviously it makes the plant the most independent of all organisms. In principle a green plant is independent of any other living thing. In practice, as we shall see, nearly all plants are influenced by others; but, as regards

its primary function of nutrition, the plant suffices for itself. Apart from this independence the whole nature of the plant is adjusted to its mode of nutrition. Its most striking feature, the possession of green foliage, is related to the necessity of having at its disposal an abundant supply of light energy. The foliage is simply a green screen which intercepts, in an extremely efficient way, the rays of light. The intensity of light inside a wood is commonly only one-fiftieth of that in the open. The whole architecture of the branchwork of a tree is related to securing the best possible display of the leaves which it bears.

WATER-SUPPLY

The spreading of the foliage to the light brings with it an unfortunate result. The leaf is a thin organ saturated with water, and, exposed to dry air, it loses water very rapidly. The amount of water which even a small plant may lose in a summer is very large; for a tree it is measured in tons. This evaporation of water, or transpiration, may be of some use to the plant; it may, for

example, serve to keep the leaves cool in the sun. But it also makes it necessary for the plant to have at its disposal a very much larger supply of water than would be necessary merely to maintain growth. To meet this necessity there is developed a root system, often of great extent, which absorbs water from the soil; and the water is delivered to the leaves by that very efficient system of conducting channels provided by the vessels of the wood. As if following a definite plan of economy of material, each of these serves a double purpose. The root system anchors the plant in the soil. The wood provides the mechanical framework which supports the foliage. On the land surface the need for water often dominates the form and structure of the plant; especially is this the case in arid situations. Water may be economised by a far-reaching reduction of the leaf surface, as we see in shrubs like the gorse or the juniper. Water may be stored against the time of want, as in the cactuses with their great fleshy stems. Plants which live submerged in water are freed from the necessity of providing a surplus supply. Absorbing freely all over their

surface, the seaweeds, often of great size, possess neither organs for absorbing water, nor internal conduits for its conduction.

PLANTS AND ANIMALS

The whole nature of the plant and the course of its evolution have been profoundly affected by its mode of nutrition. The philosopher Henri Bergson has argued that the great divergence of the plant and animal stocks is determined, in the first place, by their different ways of getting food. The animal has been active, moving about in search of prey—"The wolf the kid pursues, the kid the browse." Success has lain in the acquisition of an excellent locomotor system of limbs, actuated by muscles, informed by sense organs, controlled by nerves, co-ordinated, at last, by a brain. Consciousness has become more and more acute, instinct and intellect have become possible as the highest achievements of animal life. And all this is referable to the fact that the animal requires organic food and must move about to obtain it. Like Napoleon's army, the animal kingdom has marched forward on its stomach.

The plant need never move about, though some very simple forms do so. It needs only to absorb the raw materials which are all about it, and are constantly renewed in the air and in the water, whether of the soil or of the sea. Especially in its larger forms the function of light absorption is much better performed because it is stationary and firmly rooted. Trees do not walk and so can expand a much more efficient light-absorbing screen. In an organism of this kind there is never the necessity for rapid and accurate knowledge of what is going on around it; there is need neither for organs of sense, nor for the nerves with which they are associated. The torpor of the plant has left it in a state in which no advance in consciousness can be made. "Plants," wrote Linnæus, "grow and live, animals grow, live, and feel"; and in the difference which he thus indicated, and which is founded on the difference in the mode of nutrition, we have the chief factor in the divergent process of evolution which has made the higher plant and the higher animal such very different things.

THE INDIVIDUAL PLANT

The green plant, we say, is independent but not individualistic. The plant is a communal organism; but the second statement is true in another sense. The tree or herb is never a highly integrated individual like the dog or cat. It is, in fact, often difficult to define what we mean by a plant individual. There is little co-ordination between the branches of a tree. Buds which stand close together on a twig may influence each other in development; leaves have an effect on the buds in their axils; but twigs on different branches have, for all practical purposes, no effect on each other. Whole branches, even the whole branchwork, may be removed, and leave the tree a living entity which straightway sets about developing a fresh branch system. Further, the twigs which we remove may often be rooted in the soil, and may grow up into independent trees. Or they may be grafted on another tree used as a stock. The grafted tree leads a life which is a curious mixture of complete interdependence and complete independence. If we graft a medlar on a hawthorn, the scion supplies the stock with

organic food and the stock supplies the scion with water and salts. But the hawthorn remains a hawthorn and the medlar a medlar; neither has the slightest influence on the essential characters of the other. This is a special case, but it points the fact that the tree, or the herb, is rather a mass of parts associated for the purpose of nutrition, than an individual in the same sense as is a higher animal. And yet it is partly owing to the capacity for breaking up into parts which can go on by themselves that many plants are so markedly social in character.

DEPENDENCE OF PLANTS

We have stressed the independence of the plant, but this is only one side of the medal. It is only in the fundamental nature of its nutrition that complete independence is achieved. In its actual life it is in many ways dependent on other organisms. We will refer to two principal ways in which this is true.

The land plant roots in the soil. But the soil is not a simple mixture of inorganic material derived from disintegrated rock, although that is

the nature of its skeleton. As everyone knows, there is always present in good soil a considerable admixture of partly decomposed organic matter, the humus. This is derived chiefly from the remains of former generations of plants. The formation of good soil, therefore, depends on the plant, and the qualities which make it a suitable medium for plant growth are bound up with the presence of this constituent. Humus is partially decayed organic matter, and decay is due to the activities of a multitude of minute organisms, bacteria and fungi. The preparation of the humus is the work of plant organisms. The humus is incorporated with the soil by an active agent, and that agent is another living organism, the earth-worm. The work of the earth-worm does not end with this, but includes the incessant subterranean ploughing which continually turns over the soil and keeps it permeable, porous, and aerated. The soil is the home of hosts of bacteria, only some of which are involved in the process of decay. There are soil bacteria which are able to fix the free nitrogen of the atmosphere, and increase the supply of nitrogenous compounds in the soil; these save as a constructive agency, hav-

ing much to do with promoting fertility. We might extend this tale of the action of microscopic organisms in the soil, but what we have said may be enough to show that the soil, on which the higher plants depend, is the product of the activity of a great and varied fauna and flora, and that in this indirect way the green plant is dependent on other organisms.

The crown of the vegetable kingdom is the flowering plant. Some flowers are large and showy like those of the rose; others are small and inconspicuous like those of the oak. Whatever its appearance, the flower has as its function the production of fruit and seed. In its mature state it bears ovules within an ovary, which, if they are fertilised by pollen from the stamens, will develop into seeds within a fruit. Very often the pollen must be transferred from the stamen to the receptive stigma by external agency. In the small inconspicuous flowers of many trees and of the grasses this is usually done broadcast by the wind. In the showy flowers pollination is typically the work of insects. There are many plants, like the red currant and the red clover, which cannot produce seed if a suitable insect

pollen-carrier is not available. The details of the way in which pollination is effected are very different in different flowers, and afford some of the most wonderful examples of a fine mutual adjustment of two organisms. Only a humble-bee has a tongue long enough to reach the nectar of the red clover, and only the humble-bee can carry out pollination. The inside of a monkshood is an exact cast of the humble-bee's body, and the distribution of the monkshood is limited by the distribution of the humble-bee. The showy flower is, in fact, a structure which has no meaning except in relation to insect life. The flower, in the ordinary sense of the word, has been evolved in relation to insects and can function only with the help of insects. There are many flowers which are able to effect their own pollination if insect visits fail. But this does not affect the broad truth that flowers and insects go together, and that in this respect the flowering plant is dependent on another organism.

Once more let us say that, in its nutrition, the green plant is the most independent of living things; but that it does not have the capacity of living an individualist life in the way that many

animals do. In its mode of life it is excelled by no other organism as an example of the intricate inter-relations between the inhabitants of our earth.

Chapter III

Parasitic Plants

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Chapter III

Parasitic Plants

IN the old Norse myths we are told of Baldur, the beautiful god, who was under a doom, and whom the other gods sought to protect by taking oath from all things that they would not harm their favourite. But east of Valhalla there grew a tree-twig that was thought too weak and small to give the promise, and by it, through treachery, Baldur was slain; thus commenced the twilight of the ancient gods. The twig was the mistletoe. The Icelandic bard who wrote down the story did not know the mistletoe, which does not grow in Iceland, and in Norway only in the very south, and he missed the real point. The mistletoe was the instrument of doom not because it was small and weak, but because it was a very peculiar plant, a magic spray never striking its roots in honest soil, but springing in great bosky clumps from the branch of some tree, even of the sacred oak, and green in winter when the tree was

bare. Here was a plant to arrest the attention, to strike the imagination, to instil reverence. We find that throughout the ages, and in all lands, the mistletoe has been regarded with awe, as an agent of the supernatural. Æneas, when he descended to the shades, was armed and protected by a branch of the golden bough, which was either the mistletoe or a relative which grows on the evergreen oaks of Italy. The natives of Mabuig, an island in the Torres Straits, believe that a mistletoe can cause the birth of twins. The Ainos of Japan look on their mistletoe as a panacea. In Senegambia a mistletoe is a talisman which protects from wounds in battle. For us it may hold a special interest, for it was an essential element in the rites of the Druids of Gaul and Britain. Pliny gives us an account of its gathering, cut from the oak with a golden sickle and caught in a white cloth lest it should touch the earth, and of the sacrifice that followed. In the course of centuries the Druid with the golden knife has given way to the labourer with a pruning-hook; the oak tree can no longer supply our needs, and the orchards of Herefordshire and Normandy are laid under tribute to give us the

magic spray of the merrier rites of the modern world.

IMPORTANCE OF PLANT PARASITES

The mistletoe is the most familiar of all parasitic flowering plants. It is no chance denizen of the bough which bears it, as are the grasses which spring up on the stump of a pollard willow. It sinks absorbing suckers in the wood of the tree, its host, and absorbs from it essential nourishment. For such a plant there is no possibility of independent life, its station and its daily bread can come only from another. Many plants have taken to this mode of life, just as have many animals, and perhaps the parasitic plants are of more importance, in a sinister fashion, to mankind. The picturesque mistletoe may become a nuisance in the orchard, and the dodder may smother fields of clover and flax. More serious are those parasites of a lower order, the fungi. Our oak trees stand in danger just now from the attacks of a mildew, and ceaseless care is required to protect the vine, and, in many localities, the potato, from the ravages of blights. Rusts and

smuts are among the most serious causes of loss in cereal crops. A fungus attacking the coffee tree devastated the plantations of Ceylon, and completely changed the agriculture of that island, where to-day tea and rubber are grown instead of coffee. At the present time a fungus disease threatens the limes of St. Dominica, and has, in two years, reduced their productivity by half. All these plant diseases and many others are caused by parasitic fungi, and a good half of the acute maladies of mankind are caused by those minute and simple parasitic plants, the bacteria.

The human interest which attaches to parasitic plants is all too evident, but it is not with that aspect that we wish to deal here. The parasitic habit is even stranger in the plant than in the animal, for it is further from the normal mode of life, and to the manner and consequences of this departure we now turn our attention.

STORY OF THE MISTLETOE

The first question we might ask ourselves viewing the mistletoe on its peculiar perch is—How did it get there? The answer is that it was placed

there by birds. The distribution of plants with juicy fruits is usually accomplished by the birds which eat the fruit and carry the seed for some distance before it is dropped, usually no worse but rather better for its passage through an alimentary canal. The effectiveness of this mode of conveyance is evident from the way in which berry-bearing shrubs spring up far from the nearest fruiting specimen. But this random dispersal is not good enough for the seed of the mistletoe, which must light on a suitable branch or perish. The pulp of the berry is extremely sticky and, when a bird, typically the missel-thrush, eats it, the effect is like that of "stick-jaw" on a small boy. The bird wipes its bill on the branch on which it sits; it gets rid of the viscid pulp and the entangled seed, which stick to the twig. As the juice dries the seed is firmly glued in position and remains there till, in the late spring, germination takes place. Occasionally seeds may be voided on trees, but the usual mode of dispersal and fixation is that we have sketched. It seems that throughout the whole thousand odd species of the great mistletoe family the fruit possesses this character and the seed thus finds its proper

station. In Ceylon Sir F. W. Keeble saw hundreds of seedling mistletoes on the telegraph wires, placed there by small birds which sat on the wires to clean their bills. In this position the seedlings, of course, soon perish; but they afford a clear demonstration of the effect of the birds' action. There are species which employ different methods. At least one mistletoe, that lives on pines at Monterey in California, squirts its seed out violently when the fruit wall bursts, and sends it flying some yards, almost sure to find a place as it falls through the thick branchwork. But, so far as we know, bird dispersal is most common. Nature is a great adapter, and here we see how a slight change in a very common mode of seed dispersal has suited it to the peculiar necessities of a peculiar group of plants.

The seed germinates late in spring or early in summer, and produces, not a little root, as is ordinarily the case, but a stump of seedling stem. A normal root grows down into the soil in response to the stimulus of the force of gravity. Such a response would have no meaning in the case of the mistletoe, for the seed may find itself at the side of the branch as easily as on the top. Instead

the little stump turns away from the light, and this brings it in contact with the branch, for that is the shaded side. The base of the stump spreads out into an adhesive disc, and from this there grows a sucker which sinks through the bark right down to the wood, where it makes contact with and taps the canals carrying the supplies of salts and water in the host plant. For a year nothing further happens; only in the following summer does the young mistletoe form its first pair of leaves. In the succeeding years growth becomes more rapid, and the bush with its characteristic spreading green branches, paired leaves, and white winter berries develops.

Meanwhile, within the host the absorbing system extends. From the neck of the first sucker outgrowths are produced which grow in the living tissue just outside the wood, and run far up and down the branch. They always grow along the branch and never girdle it, so that the branch is never strangled. These outgrowths are not themselves absorbing, but every here and there they send down fresh suckers into the wood. Now the wood of a tree grows in thickness and so tends to embed the suckers. It does not do so, for, just

at the point where it enters the wood, the sucker possesses a zone of active elongation which keeps pace with the increasing thickness of the wood. In time the point of the sucker becomes sunk in the wood, but the sucker as a whole is not overwhelmed. An apple bough split through a region of infection shows the suckers like a row of little conical tacks driven into the wood, diminishing in length with their distance from the original position of the seedling. From the outgrowths, which run along inside the host branches, there arise too, at intervals, buds which grow out and develop into new mistletoe bushes, and in this way the host is still further exploited. This makes it difficult to rid a tree of the parasite, for, if the branches are not cut back far enough, the parts left may contain enough of the parasitic growth to produce new buds and so continue the attack.

In one way the mistletoe is not a thoroughgoing parasite. From the host plant it takes only salts and water. Its leaves and branches, and even the internal outgrowths, are green and, so far as we know, function normally in building up organic matter; to this extent the parasite is

independent of its host. The mistletoe is only a partial parasite. It takes from its host only what a normal plant takes from the soil. It might thus appear that its relation to the host is not a highly specialised one, that here is a plant that, instead of rooting in the soil, roots in another plant. But such a view does not do justice to the situation. The mistletoe does not take root in its host, because its absorbing suckers cannot be regarded as roots. They are not formed like roots, they do not grow like roots, and they have not the structure of roots. Moreover, they are quite incapable of growth in the soil or anywhere except in the tissues of a suitable host. In this our parasite shows a definite departure from the normal. Then the capacity of withdrawing water from a living plant requires a fine adjustment of suction forces. The leaves of the host plant draw on the water supplies in the stem and branches; the parasite must be able to make good against this competition. It does this so effectively that it deprives the host leaves which stand above it of their supply, so that they are starved; some tropical species cause serious damage to the host in this way. The parasite, like young Sam

Weller, must possess a "werry fine power o' suction." Finally, we have the fact that the parasite is restricted to definite hosts. Our common mistletoe is found, especially on the Continent, growing on a great variety of trees. But it has been shown that it really exists in three different races, resembling each other very closely in appearance, but differing in the trees they affect. One grows on the pine and a second on the fir. Each of these may also grow less commonly on a few other conifers. The third grows only on broad-leaved trees—it is the race we have in this country—favouring some, such as the apple and poplar, rare on others, such as the hawthorn and horse-chestnut. It is least common on the oak, and in this country there are only about a score of mistletoe oaks known. What the factors are which differentiate these races, and enable them to utilise one kind of tree and not another, we do not know. There are probably difficulties in the way of penetrating tough bark, and the presence of chemical substances, like the tannins of the oak, may be against the thriving of the parasite. But there must be more in it than this; we are dealing with a very delicate adjustment between two plants,

and this shows most clearly how highly specialised a parasite the mistletoe really is.

GRAFTING

There is another relation between two plants which, at first sight, has much in common with that of the parasite and its host—the relation between the scion and stock of a graft. Grafting is, of course, usually an artificial relation, but natural grafts, for example between the branches of beech trees, are found, and it is said that natural grafting between roots is very common. In a graft we have a scion of one variety, for example a pippin, growing on a stock of another, for example a crab-apple. Two cut surfaces have been allowed to grow together so that the two components have become, as regards nutrition, one plant, each, however, maintaining its own specific features. Between the pippin drawing its water and salts from the crab, and the mistletoe taking the same supplies from the pippin, there seems to be much in common; yet the resemblance is quite superficial. The mistletoe cannot be grafted on a host; it can make good its

footing in its own peculiar way only. Grafting can only be successful if the stock and scion are nearly related; often they are different races of the same species. But the mistletoe grows on a variety of trees which are in no way related to it. Most important is the fact that the relation between the stock and scion is mutual, while that of the parasite and its host is one-sided. The scion takes water and salts from the stock and gives back organic food, for the stock is always robbed of branch and leaf and is incapable of subsisting by itself. The mistletoe gives back nothing. The experiment has been made of growing a mistletoe on a young apple tree and, when it was fully established, of removing all the apple foliage. For a year the union subsisted and then the apple died from starvation and with it the mistletoe.

THE ESSENCE OF PARASITISM

The essential features of the parasitic relation are the complete dependence of the parasite on some other living thing for necessary food substances, and the complete lack of reciprocity. In

some other flowering plants we see the degree of dependence much intensified.

THE STORY OF THE DODDER

On the Surrey heaths the ling and thyme are often tangled with a mass of fine reddish threads, which are, in late summer, studded with clusters of little, pale pink bells. This is the dodder. Other species, coarser and yellow in colour, grow on the clover and the flax and may do much damage when the crops are heavily infected. The dodder is another parasite, one which has gone to much greater extremes than the mistletoe. Let us follow the history of the clover dodder. Its seeds have fallen to the ground in the autumn, or they may have been harvested and sown with the clover seed. They require a high temperature for germination, and so lie dormant till summer. This is advantageous, for it means that there will be abundant young clover plants ready for the dodder when it germinates. From the seed there issues a little yellow thread an inch or two long. At one end there is the vestige of a root, which never enters the soil, though it may absorb some

water. The tip of the thread rises from the soil and slowly moves round in a circle, at the same time growing forward. This may go on for some days, the material for growth at the apex being supplied from the base, which withers away behind. Creeping along and circling, the curious little yellow, leafless seedling gives an impression of seeking for a host. When it chances to touch a clover it makes several close tight coils round it, and, from the inside of these, suckers are sent down into the host. There is now a source of food substance at its disposal and it begins to grow vigorously and to branch. It makes long loose coils round the stems and leaf-stalks, alternating these with a few close tight coils from which more suckers are produced. This mode of growth is very interesting. The dodder is a member of the bindweed family and its loose coils resemble the coils of a twining plant. The tight coils, however, are like those of a tendril, and like them are made in response to the stimulus of contact with the solid stem which it touches. Here we have a modification of the ordinary mode of twining, an adjustment to the peculiar necessities of the parasitic dodder. Twining and branch-

ing, the original seedling ultimately extends into a tangled mass of threads, the "devil's twine" of the apt German common name.

Unlike the mistletoe, the dodder is a complete parasite. The clover dodder has no green pigment; some other species have a little, though never enough to enable them to build up the organic matter required for growth. The dodders are thus dependent on their host not only for water and salts, but also for their supply of organic food, carbohydrates and proteins. The suckers of the mistletoe make contact with the water-conducting wood, those of the dodder tap, as well, the living tissues from which organic food may be absorbed. This increased dependence on the host has made possible a notable reduction in structure. The dodder has lost not only its green colour, but also its leaves; foliage is represented only by a few minute, yellow scales. Instead of the stout twining stem of the bindweed rooted in the soil, often to great depths, and bearing broad foliage leaves, we have the slender twining stem of the dodder, rootless and leafless. Its suckers may, though this is not certain, be of the same nature as the stem roots of

the ivy. The flowers remain like those of the bindweed, though smaller; they are produced in great numbers, as is indeed very easy for a plant which blossoms and fruits at the expense of another.

SIMPLIFICATION OF PARASITES

With functional dependence goes structural simplicity, a simplicity which is, of course, due to loss. In extreme cases this simplicity may go very far. In one tropical family of parasites, the Rafflesiaceæ, the whole vegetative body of the parasite may live inside the host plant, reduced to a spreading weft of undifferentiated filaments, root, stem and leaf alike lost. In these plants the flowers are still retained. They burst through the bark of the roots and stems of the hosts, strange and foreign blossoms, of brilliant colouring. One of them, the giant Rafflesia Arnoldii of Sumatra, is the largest known flower, reaching the immense diameter of a yard. The vegetative organs losing their normal food-producing functions may be dispensed with or may be modified to fit new needs; the reproductive organs are

usually unaffected by the parasitic mode of life, though in some cases they show peculiar features which seem to indicate an even more profound effect of the radical change of habit.

ORIGIN OF PARASITISM

One interesting problem raised by the frequency of parasitism we have not yet touched on, and that is the way in which the habit has arisen. Some light is shed on this by another group of parasites, among which the toothwort and broom-rapes are not uncommon in England. These belong to an alliance that includes such familiar plants as the foxglove, the eyebrights, the snap-dragons; these three and the toothwort belong to one family, the broom-rapes to another. Toothwort and broom-rape are complete parasites; but in the foxglove family there are many partial parasites whose nature is scarcely betrayed by anything in their appearance, except, perhaps, a certain scragginess of growth. The eyebrights, the yellow rattle and the cow-wheats are familiar examples. All these plants are attached, by their roots, to their neighbours in the grassy pastures in

which, by preference, they grow. The eyebright and the yellow rattle can, if sown in soil free from other plants, complete their life-cycle independently; but they do better if they can attach themselves to grasses and other herbs. The cow-wheats must have external aid. It is known that all these green plants can build up organic food normally; it is the supply of water and salts which requires augmentation. But Tozzia, a plant of the same family, which is found in the Alps, lives underground, as a complete parasite, for the first year of its life, and in the second sends up a flowering shoot with rather fleshy, yellow-green leaves. It has lost most of its capacity for assimilation and draws most of its organic food from its hosts. A further stage is reached in the toothwort, which is a parasite on the roots of hazels and other trees in this country. Underground it has a branched stem with many fat, white scale-leaves, and from this flowering shoots are sent above the soil, purplish in colour, and devoid of chlorophyll. The toothwort is completely dependent. Finally, we have the broom-rapes. Their tiny seeds, washed into the soil in thousands, can germinate only if they are

in contact with a suitable host, the broom for one species, the thyme for another, the bedstraws for a third. The seedling immediately pushes a sucker into the host root, and forms on it a little tuber. Secondary suckers augment the supplies. From the tuber there arises in time a tall flowering spike, with a few scaly leaves and of a dingy brown or purple colour. The broom-rapes again are complete parasites, and they have lost most of their vegetative body; there remains only the absorbing system and the flowering spike.

Here we have a number of related plants that show us the stages by which the complete parasite has evolved. We do not mean that these plants form an actual line of descent, but we suggest that the independent ancestor from which started the series that has led to the broom-rapes we know, very probably gave rise, in the first place, to a variant which was able to utilise its neighbours in the way our eyebrights do to-day; that this led to a stage where the external aid could no longer be dispensed with, as in our cow-wheat; that this was followed by a Tozzia-like stage, and so on. It is almost impossible to imagine a plant like the broom-rape, with its reduced struc-

ture, its fine adjustment to a strange mode of life, its intricate inter-relation with its host, arising complete in one step. Its origin is illuminated, and made, as it were, reasonable, when we look on it as the culminating stage of a more or less gradual process of evolution, the steps of which are illustrated for us by still living plants in the circle of its kinship.

But we are far from understanding the nature of the factors which have led to the change of habit. We are inclined to lay stress on the importance of opportunity. A plant growing, as does the eyebright, or yellow rattle, in a sod thick with the roots of other plants, has every opportunity, in constant contact, of entering into a still closer union with its neighbours. It does not seem strange that some plants should have seized the opportunity. In other parasitic groups opportunity of a different nature has been present. The dodders belong to a family of twining plants, and here again we have a very intimate contact with the supporting stems giving the opportunity for a step towards a greater dependence. In this respect the mistletoes are the greatest puzzle, for they form a self-contained family with no rela-

tives which can give us a clue to the mode of life of their ancestors. The family is predominantly tropical, sending a few representatives into the cooler zones north and south. In Europe there are three species, in England one, while in the tropical forests there are about a thousand. Among these there are many with brilliant and beautiful flowers and fruits, and there is also a much greater variety in form and habit. Where our mistletoe joins the branch of the host there may be a local swelling or knob. In South America some mistletoes cause the host branch to grow out into a great convoluted cup of wood, in the centre of which the parasite has its seat. Some tropical species have long twining stems, which send suckers down into the host; others have tangles of twining roots. This gives us a hint, for the twining stem suggests that the ancestral mistletoes may, like the ancestral dodders, have been climbing plants. Another possibility is that they were epiphytes. The tropical forest is rich in plants which live habitually on the trunks and branches of trees, finding there a foothold but making no more intimate connection and drawing no nourishment from the trees on which they

live. Such a mode of life would provide another kind of opportunity for the first steps in parasitism. Nor must we lose sight of the mistletoe berry. It is eminently suited to secure for the seedling parasite its proper station in life; and if such a berry were possessed by the independent ancestors it might have given the opportunity which we believe to be essential; it might even have forced a parasitic or at the least an epiphytic life upon its possessors. For the mistletoes we have thus a choice of at least three ways in which the habit may have begun; perhaps the most probable is that commencing with a climbing ancestor; but we have scarcely enough evidence to balance even probabilities.

Important though a suitable opportunity certainly has been, it can be regarded only as one, and perhaps a minor, factor in the evolution of a parasite. For there are innumerable climbing plants, and very few parasites of the dodder type; and the majority of plants are rooted in soil rich in roots, yet the number of root parasites is relatively insignificant. We can scarcely believe that the ancestor of a parasite was a weakly strain, which, in its weakness, took to preying on other

plants, surviving by virtue of their aid. Plants do not, in general, have the power of sending suckers into a host, or of adjusting their roots to the performance of so strange a function as the withdrawal of nourishment from another plant. Attempts have been made to produce parasites experimentally, but they have so far failed. Seeds allowed to germinate in wounds in other plants may produce seedlings which survive for a time, rooting in the looser tissues of the host. But they make no real approach to sucker formation; and, so far from benefiting by the association, they are always stunted and starved. The capacity for making the necessary intimate contact in even the most elementary type of parasitism is clearly a positive acquisition, and this must have been the first step in any series. Only a plant which acquired this power, and had suitable opportunities, could take the first step.

A THEORY OF PARASITISM

We wish to put forward the view that parasitism, in its origin, is not the last resort of the feeble, but a positive step forward, on a new,

though it may be downward, path. This may be followed by a reduction, which it is usual to regard as degeneracy, but this is not a necessary consequence. Again we must refer to the great mistletoe family. With perhaps a single exception all the mistletoes are green; they have well-developed foliage, and they build up their own food like other green plants. Only water and salts do they withdraw from their hosts; to be able to do so they have evolved a very highly specialised absorbing system. They do not show reduction and they cannot in any sense be called degenerate. Nor can we look on them as plants which have just taken the first step, and which are doomed to proceed on a downward path, ending in a state like that of Rafflesia, without root, without leaf, without stem. A compact and sharply defined family with all its members practising parasitism of the same type must have a long parasitic ancestry behind it, and would certainly show distinct signs of further change did these necessarily follow the adoption of the habit. Reduction is not a *necessary* consequence of parasitism; it is a further departure which is, in fact, very general.

The beginning of reduction can be seen in some plants which are not parasites. Indeed a very frequent sport in many plants is the appearance of a golden-leaved variety—well known in elders, elms and privets. Such a variety is one that cannot produce the normal quantity of chlorophyll. As a rule it is ill-nourished and perishes in nature. It can be maintained by careful treatment in cultivation, and many golden varieties are so maintained, apparently because some people think them more beautiful than the normal green-leaved forms. But in a plant which had adopted the parasitic habit the change to a golden-leaved form would be less serious, for there would be the opportunity of making good deficient powers of assimilation by drawing on the food substances of a host. We may look on Tozzia as a rather advanced golden-leaved stage, the first step in the process of reduction. Albino plants with white leaves also crop up as sports in nature and in cultivation; they, of course, die as seedlings; but in a stock already parasitic they might persist. By similar steps the now useless leaves might be reduced to scales, as in the toothwort, to minute scales as in the dodders, to nothing as in Rafflesia.

In such parasites as the dodder and Rafflesia there is a very far-reaching reduction. The advanced parasite has come to be dependent on its green host for organic food in the way all animals are dependent on green plants; it has departed from the norm of its kind; it has lost much, but it is admirably fitted to the life it leads, and its losses are of things now useless to it.

DIVERSITY OF PARASITISM

The examples we have given serve to illustrate another point about the parasitic habit—that it can be pursued in very diverse ways. Apart from the distinction between complete and partial parasites, we have seen that in both these classes there are great differences in the mode of attack. The root-parasites, some of which possess true roots of their own, attach themselves to the roots of their hosts underground. In one tropical family the host root actually sends conducting strands into the tuberous body of the parasite. The dodder twines round stem and leaf. The mistletoes range from isolated bunches of spreading twigs, through stem twiners, to root twiners. Some of

the sandal-woods, which are partial root-parasites, are herbs, others shrubs, and yet others trees. The parasitic habit has not stamped a common form on its followers; it has permitted as full a play to organic diversity as has the normal mode of life. Rather it has added to normal diversity a varying touch of strangeness.

PARASITISM ORIGINATING SEVERAL TIMES

It is almost unnecessary to point out that the parasitic habit has arisen not once only in the course of the evolution of the flowering plants, but several times. The dodder and the mistletoe belong to very different families of plants; the broom-rapes are not related to the Rafflesias. But the habit has not arisen very often. The parasites may be referred to about a dozen families, and we may infer that the special changes, that have made their evolution possible, have taken place in a limited number of plant groups. That these changes may still be going on is suggested by the fact that in the foxglove family there are partial parasites showing different degrees of dependence.

Parasitism is a biological habit which has been adopted in different groups of plants quite independently, and in this there is an interesting parallel with the other peculiar modes of nutrition, which have been adopted by the flowering plants. There is the saprophytic habit, followed by those flowering plants that, aided by an association with symbiotic fungi, live on the dead and decaying organic matter of the soil. These plants, too, are without chlorophyll, and, in many ways, resemble parasites like the toothwort or broom-rape, though they do not make contact with any living host. We find that saprophytism has been adopted by some members of the heath family, for example by the Indian pipe and the bird's-nest, and by some members of the orchis family, for example by the bird's-nest orchis and the coral-root. These two families stand very far apart. The habit of increasing the supply of nitrogenous compounds by harbouring bacteria in root swellings has been adopted throughout the great pea family, and also by such different plants as the alder and the bog myrtle. Strangest of all these strange modes of nutrition is the habit of trapping and digesting insects. Our common

insectivorous plants belong to widely separated families, the sundews to one, the butterworts and bladderworts to another. All this illustrates the fact that very similar results may be reached by evolution along very different lines. And we may note that this applies not only to biological habits, with which we are here concerned, but also to form and structure. There are desert Euphorbias in South Africa which closely resemble desert Cactuses in America; there is a Veronica in New Zealand which, when it is not in flower, is almost indistinguishable from a cypress.

NON-FLOWERING PARASITES

The flowering parasite is so striking in its departures from the ordinary flowering plant, and illustrates so well the diversity of this kind of life, that we have given it prominence. But flowering parasites are really insignificant alike in numbers and in economic importance when compared either with normal flowering plants, or with the parasitic fungi. To these we must now give a little attention. The fungi form a great and heterogeneous class of plants at a low level of

organisation. None possess chlorophyll; all are dependent on external sources of organic food. It is generally supposed that they have been derived from the algæ, and that different groups of fungi have arisen from different points of the algal stock. They are characteristically land plants, though a few occur as parasites on seaweeds, and in fresh water. "The sea's abundant progeny" keeps the waters free from any accumulation of dead organic matter, and it is on land, where such accumulations are abundant, that types like the fungi have their opportunity. Perhaps the majority of fungi are saprophytes, playing an important part in the gradual reduction of dead matter to simpler substances, which may once more be used in the nutrition of green vegetation. A very familiar example is the blue mould, which makes its home on the most diverse substances, from jam and cheese to old boots. But very many fungi are parasites. These probably arose from saprophytic forms; some can still live in either of the two ways, according to their opportunities; others are highly specialised parasites which require not only a living host but one of a particular species.

The parasitic fungi are most important when they cause plant disease. They are, in fact, the chief agents of plant disease, and frequently cause serious economic damage. Their modes of life are varied, and we may illustrate this with reference to some species which affect our food plants. The "wart disease" of the potato is caused by a minute organism, of simple structure but complex life history, which lives within the cells of the tuber. It causes the plant to produce the great warty outgrowths which make the tuber useless. It lies dormant in the soil, in the form of resistant spores, for many years, and is extremely difficult to destroy. It can be combated at present only by using immune varieties of potato. Its importance is indicated by the fact that in many districts only these immune varieties may be planted.

Another important potato disease is the "blight," caused by a filamentous fungus, which infects the leaves through the stomata. It can penetrate the living cells, and not only withdraws food from them but secretes an active poison. A badly infected plant is rapidly reduced to a brown and putrid mass of decaying leaf and

haulm. This fungus sends little threads out through the stomata, and on these are formed innumerable minute reproductive bodies, or spores, which are scattered by the wind, and, in moist warm weather, spread infection very rapidly. Happily in this case, as with a similar disease which affects the vine, infection can be much reduced by spraying the foliage with poisonous copper compounds. In districts subject to these diseases systematic spraying is part of the normal routine of cultivation.

The "mildew" which affects such plants as the rose, the pea, and the oak is caused by fungi which live on the surface of the leaf, and send absorbing suckers into the cells of the epiderm. The fungus coats the leaf with a white powder of spores, cuts off its light supply, and exhausts it. The most important mildew, economically, is the American gooseberry mildew, a remedy for which by spraying has only very recently been discovered. The mildew fungus can live only as a parasite, while the fungus which causes blight can be grown artificially as a saprophyte.

The "smuts," some of which grow on the common cereals, live in the growing point of the

plant and infect the flowers and fruit. Instead of a normal seed the oat or barley attacked by smut produces a grain filled with a mass of black powdery spores. The smut fungi spend part of their life in the soil, and some of them can be grown through the whole of a complex life-cycle as saprophytes. In nature, however, they always require a living host, of a particular species. Most highly specialised of all fungal parasites are the familiar "rusts." They take their name from the rusty-looking stripes and patches of spores which appear on the leaves and stems of affected plants. Several species grow on the cereals and cause considerable losses. We may take as an example the classic case of the black rust of the wheat and other grasses. The fungus lives between the cells of the young leaves of the wheat and produces fructifications which cause orange stripes on the leaves in early summer. Scattered by the wind the spores may alight on the leaves of the wheat and germinate at once if the leaf is moist. They infect the leaf through the stomata and repeat the former history. Late in summer, however, another type of spore is formed. Instead of being thin-walled and light

red in colour it is thick-walled and black. It has the power of withstanding adverse conditions, and it cannot germinate at once. It carries the fungus over the winter months. Germinating in spring, it produces spores of yet another type. These can infect a host plant, but not the wheat. The vegetative body they form can live only in the leaves of the barberry, which the infecting thread enters through the walls of the epiderm, and not through the stomata. On the barberry leaves a new kind of fructification is produced, in the form of little "cluster-cups" on the underside of the leaves. The spores from these re-infect the wheat and so the complex cycle is completed.

This is clearly a very high type of parasitism, for it necessitates an accurate adjustment to the different environments offered by two separate hosts. The degree of specialisation is further emphasised by the fact that such rusts often exist in a number of races, comparable to those of the mistletoe, each restricted to one particular host species in each stage of its life-cycle. Many rusts have abandoned the full cycle by omitting one or more of the spore forms, and by restrict-

ing themselves to a single host. None of the rusts can lead a saprophytic life.

We cannot here give any idea of the variety of form shown by the vegetative bodies and, more especially, by the fructifications of these fungi, but we have given some indication of the diversity of their modes of attack, and of the effects they produce. Some live outside their hosts, sending suckers into the living cells; others live inside the host, but are confined to the spaces between the cells, and such may or may not send-suckers into the cells; yet others live entirely within the cells. Some enter through the cell walls, piercing these by local pressure, and by the action of solvent ferments; others can enter only through the stomata; yet others, like the important fungus which causes larch canker, can enter only through wounds. Some are a drain on the resources of the host; others poison it as well; yet others are responsible for peculiar malformations, such as cankers, and the curious witches' brooms so common on the birch. In form they have a range almost comparable to that of the whole group of flowering plants, in mode of life they are much more varied than the flowering parasites.

The plant is essentially an independent organism. We have seen the fundamental importance of its type of nutrition in maintaining the conditions which make the life we know possible. But we must not lose sight of the very large number of plants, for the most part belonging to the fungi, which have abandoned this vegetable way of life, and which feed on the same level as the animals. Living as saprophytes, these plants take an essential part in keeping up the circulation of matter, in preparing the way for the successful growth of green plants in the soil. Living as parasites, they are, in essence, harmful. In wild nature the development of immunity, and, especially, healthy growth in proper conditions, tend to keep down the ravages of parasitic forms. In the more artificial conditions of the field and of the garden man's utmost vigilance is necessary to keep them in check; just as, in the artificial conditions of civilised life, a very great expenditure of thought and energy is required to combat the epidemic diseases due to certain bacteria, which must be reckoned as the most dangerous of all the parasitic plants.

Chapter IV

Parasitic Animals

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Chapter IV

Parasitic Animals

PARASITIC animals are not popular. Man himself, being one of the natural victims, is not attracted to creatures with this mode of life. Some of them are adapted to living in his alimentary canal or upon the surface of his body, and he does not care for this kind of thing. Many are somewhat repellent in appearance; others he may have learned have a rather inglorious ending to careers which begin in a promising way. And there is the unpleasing association in the term "parasite" with that type of human individual who sponges on his fellow-man.

A BROAD VIEW OF PARASITISM

If, however, we are to entertain a just appreciation of Nature's ways in this realm of life which we are about to survey, it is desirable that we should divest our minds of prejudice and error. It is unfortunate that the term "para-

site," with its evil association in relation to man, should be applied to animals. For the sake of clear thinking in our study of this subject, it may be useful at this stage to point out here what are obvious fundamental differences. In man the practice is a characteristic of the actions of particular individuals in relation to others of his own kind, and varies in form and degree in accordance with personal inclination and opportunity. It is a matter of individual behaviour. In the case of animals all the members of a parasitic species have the same habit. They never establish themselves upon members of their own species, but upon those of another and usually distantly related one. They maintain their existence in this way from necessity, not from choice. They do so in virtue of inherited structure and habit; their actions, it need hardly be said, are devoid of moral significance.

This, however, is only partly reassuring. There remains the unpleasant fact that man in quite a large number of instances plays the host to very unattractive types of parasitic life. But after all we are concerned with a mode of life of which human experience is but a little part, and even in

that only certain elements are repellent in the ordinary sense. Some knowledge of the organisation, life histories, variety and complexity of inter-relations, habits and instincts, enables us to take a better balanced and truer view of the parasitic habit as a mode of life.

. . . .

The world, viewed as a habitat of animal life, presents to our minds a field of varied and complex conditions. The inherent character of living matter, *i.e.*, protoplasm, the stuff of which organisms are made, is such that wherever nutritive and appropriate physical conditions prevail, there are living organisms to be found. The various regions of the oceans, rivers, lakes and dry land swarm with organised beings, suited in structure and function to their particular environment. It is only in keeping with this tendency to penetration by life, that within these various regions, which in process of time have yielded subsistence and shelter for myriads of animal forms, the animal body itself, providing food and protection in a highly favourable degree, should inevitably become an area of occupation to a wide variety of living creatures.

DIVERSE WAYS OF FEEDING AMONGST ANIMALS

Nutrition being a fundamental necessity for living, we may therefore view the habitable regions of the earth as constituting a group of "nutritional areas," and include as one of these the animal body itself.

For our present purpose the modes of nutrition amongst animals may be classified very simply as follows:—Some feed exclusively upon plant substances, others upon a mixed diet of plant and animal, and in the case of others again the diet is exclusively of an animal nature. Within this last group, which more immediately concerns us, there is a wide range of creatures equipped for the capture of the living animals which they devour. These belong to the category of predatory animals. We must place a broad interpretation upon this term, which in this connection is applicable to small as well as large creatures, and to insidious and subtle attack as well as violent. A specialised form of predatory activity is that in which the victim is so exploited that it serves the purpose not simply of

a single meal, or of a family's temporary provisioning, but that without immediate sacrifice of its own life it serves both as an area of occupation and a provision of the means of subsistence for the whole normal life of the invader or for an essential stage of it, at least. Relations of this nature are never transient; they are never casual as between attacker and attacked; they tend to be specialised between species. Doubtless in many cases the habit evolved from the predatory habit, especially amongst the more highly endowed animals such as insects, but it is more probable that amongst single-celled animals and worms of various kinds the habit had its beginning in casual associations.

DISTRIBUTION OF PARASITES

The parasitic habit appears to have existed a long time ago, since parasites of Cambrian age have been described. Further interesting evidence of this nature may be found in the fact that the external parasites of certain birds have afforded confirmatory evidence of relationship with regard to their hosts, and incidentally of

long-established associations with their hosts. Probably the best example of this is to be found in certain external parasites of the wingless bird of New Zealand, known as the kiwi (*Apteryx*). This bird which resembles generally other flightless forms, the emu, rhea, and ostrich, has been regarded by eminent authorities on the structure of birds as being related to the family of rails amongst flying birds. This implies a connection of great antiquity. It has been pointed out as an interesting corroboration of this theory that there occur upon the body of *Apteryx* certain wingless, biting, parasitic insects belonging to the same genus (*Rallicola*) as is characteristic of the members of the rail family of birds. With rare exceptions they are not found on other birds, and not at all on other flightless forms. Professor Kellogg and others who have studied the life and relationships of these parasites regard the distribution on these particular birds as of such long standing as to be confirmatory of close blood relationship between their bird hosts. "The distribution of these wingless permanent ecto-parasites is governed more by the genetic relationships of the hosts than by their geographical range

or by any other ecologic conditions" (Kellogg).

Animal parasites occur almost exclusively amongst Invertebrates. There is no doubt that size in animals has been a limiting factor in the evolution of this habit, and this has much to do with its restriction to the backboneless section of the animal kingdom. Inside this series their occurrence varies considerably within the several great groups or phyla. The nearest approach to completely parasitic phyla are the flat Helminths or "Worms" and the round Helminths. Several *classes* are entirely parasitic, *e.g.*, the Sporozoa amongst the unicellular animals. Amongst Arthropods, notably among the Crustaceans and Insecta, whole families and super-families are given over to parasitism. Only amongst the Porifera or sponges and Echinodermata have no clear cases of parasitism been recorded. On the other hand, all classes of Vertebrates serve as hosts for animal parasites.

It is now proposed to illustrate by reference to particular examples some of the outstanding features of the parasitic habit. Since, as has been already indicated, parasitism has arisen independ-

ently at many different levels of the animal series, the order in which the examples are given must be regarded as emphasising the mode of the parasitism, not the position of the particular type in the animal kingdom or its emergence in the evolutionary process.

LIFE-HISTORY OF LERNÆA BRANCHIALIS, A CRUSTACEAN PARASITE OF THE HADDOCK

Typical members of the class Crustacea are equipped with a firm shell-like covering, specialised sensory apparatus, and highly efficient swimming and walking limbs. They are of active habit. When the naturalist Linnæus encountered the subject of the present study he failed to recognise its true zoological nature, and classified it as a soft-bodied worm (*Vermes mollusca*).

On the gills of the haddock, and other members of the same family (Gadidæ) there may frequently be found, firmly attached by tough root-like structures, a soft curved worm-shaped body about an inch in length, and of a blood-red colour. A closer examination of this somewhat shapeless creature reveals the presence near the attached

end of several pairs of feet of the swimming type, but in a dwindled or vestigial condition, and of an abundance of eggs in a pair of slender thread-shaped strands attached to the posterior part of the body. When the ripe eggs are released they float away into the sea, and from each there emerges a minute oval-shaped animal with three pairs of appendages by which it swims energetically. Any doubt which may have existed as to the nature of the creature from which they arose is now dispelled, for this minute form is at once recognisable as a larval stage of a member of the division Copepoda within the class Crustacea. In technical language it is a Nauplius larva. In ordinary types the Nauplius larva passes through a series of growth stages and assumes the Copepod form with well-developed swimming feet and active habits. But the Nauplius of the parasite we are discussing, *Lernæa branchialis* by name, attaches itself on the earliest opportunity to the gills of a fish of the flounder type, clinging first by means of a claw-like joint upon its feelers, and later by a glandular cement formed on its head. The appendages now atrophy, losing their swimming hairs, but the body increases in size, suste-

nance being obtained from the gills of the flounder. This marks the first stage of parasitic life.

After a time of feeding and growth, the atrophied legs resume their active form, Lernæa detaches itself and again becomes a free-living crustacean, now with more or less typical Copepod features. The two sexes are now distinguishable and pairing takes place. On the accomplishment of this function, the males pass out of ken, but the females survive and now seek out a fresh host, this time a member of the cod or haddock family. Again they attach themselves to the gills, but now they develop root-like processes by which they firmly fix themselves and are able to sustain themselves on the blood of their host. All structures normal to a creature of active habits disappear or remain in a vestigial condition; the alimentary canal remains and the sex organs develop enormously, while the body, greatly increased in size, assumes the worm-like appearance we have already noted. The future of the parasite is assured for another generation.

In the simplification of the limbs during the first phase of parasitic life, in their recovery of form in relation to the free interval in which pair-

ing is accomplished and an exchange of hosts is effected, and in the subsequent retrogression when the final host is attained, we have significant illustrations of a deep-seated capacity for structural adjustment to the precarious circumstances of a parasitic life.

SACCULINA; A CIRRIPEDE CRUSTACEAN, PARASITIC ON CRABS

An interesting group of Crustaceans which in some of its members exhibits remarkable features of parasitism is the order of Cirripedia. The most familiar examples of this order are the barnacles and acorn-shells, the former living attached to old wooden piers or ships' bottoms, the latter on shore objects such as shells, seaweeds, or rocks. All Cirripedes pass through changes in development involving in the growth period two free swimming stages, namely, a Nauplius form and a Cypris. These are normal juvenile stages with masticatory and locomotor appendages, a sensory equipment in the form of simple eyes, and an alimentary canal. In the non-parasitic adults these are retained, and on the attainment of this stage

in the barnacles and acorn-shells the trunk appendages become long curl-like, two-branched limbs which sweep the surrounding waters and waft food towards the mouth.

Sacculina is a parasitic Cirripede found protruding as a large bean-shaped structure from the under-side of the body of affected crabs. From eggs liberated into the sea there hatch larvæ of the Nauplius type, resembling generally those of other Cirripedes. There are notable differences, however. They have no alimentary canal. And, while functional swimming limbs are present, there are no masticating hooks, which are a feature of these limbs in the Nauplius of non-parasitic Cirripedes. This form is succeeded by a Cypris stage, which also is devoid of food canal as well as the usual eye of a typical Cypris larva. The limbs with their appropriate muscles are developed, in striking contrast to the absence of other body organs. It is apparent that the functioning of the individual life as manifested in feeding and growth is already undergoing suppression in anticipation of the racial needs which completely dominate the adult condition.

For a few days the Cypris swims in the sea. Its

whole future depends upon the efficiency of its swimming limbs and their muscles, together with its nervous and sensory structures which enable it to find and attach itself to the body of a crab. Failure here means elimination. And further, there is no certainty of a future for the Sacculina unless the crab is undergoing or has recently undergone the moulting process. The minute Cypris attaches itself by means of its antennules at any point of the crab's body where there are bristles, at whose base the husk or cuticle is softest. Fixation having been effected, the whole of the hinder part of the Cypris body, containing the swimming limbs and their muscles, is detached and set adrift. Around the minute attached part which contains cellular tissue a new skin grows, while within, a hollow boring organ makes its appearance. This structure, known as the "dart," perforates the skin of the crab, while along its hollow core there passes into the body of the crab a formless mass of cells. It is possible that these are surviving undifferentiated cells persisting through the Nauplius and Cypris stages. Within the crab the cell mass drifts with the blood and eventually comes into attachment with the intestinal wall.

Root-like ramifications penetrate this and absorb nourishment. The Sacculina enters on a new growth. A simple body without appendages of any kind is formed, and predominant amongst the parts which shape themselves in each individual are organs of both sexes. In proximity to the parasite the outer covering and related parts of the crab's body soften and degenerate, permitting the protrusion on the under-side of a sac-like mass of the shape and size of a small bean. This is the adult Sacculina from whose fertilised eggs arise the active Nauplii to whose existence in the sea we have already made reference. They are the young of a new generation.

This is a type of parasitism exhibiting somewhat extreme features. In early life, both in the Nauplius and Cypris stages, there is a suppression of structures relating to the individual's needs in ordinary living; this is followed, as soon as a host is secured, by the formation of a new body, wholly subservient to those functions which concern the continuance of the race. It is a climax of living, simply in order that the race may live!

A striking effect upon the crab infested or parasitised by Sacculina is that female crabs suffer

partial or complete castration, whilst males in varying degrees take on the features of females. In some cases they become actually hermaphrodite.

TAPEWORMS

The group of animals known as Tapeworms or Cestodes furnish an illustration of parasitic life which carries with it a repugnance scarcely equalled by that felt for those external insect parasites which infest the human body. This dislike is doubtless in large measure due to the fact that the adult worms live in the intestine amongst its food contents; and it is also due to their unattractive appearance, coupled with the very great length to which those which are best known may attain. Amongst Vertebrate or Backboned Animals they are widely distributed; and in the lower forms, *e.g.*, marine fishes, they are extremely common. Some are quite small, measuring only a few centimetres in length, and it is usual for such forms to be numerous in a single host. Tapeworms are common in domestic animals, both in the infective and adult stages,

and it is regarded as probable that Moses was familiar with their frequency in certain animals when he forbade the use of the pig and other "unclean" animals as food. The occurrence of a tapeworm in the food canal is the result of the swallowing of a passive cystic or bladderworm stage in the flesh of the prey ingested, or, in the case of man, of the eating of inadequately cooked infected flesh. The life-cycle of a tapeworm will be understood best by considering a particular case.

THE LIFE-CYCLE OF DIBOTHRIOCEPHALUS LATUS, THE BROAD TAPEWORM OF CYCLOPS, PIKE, AND MAN

The adult form of this tapeworm lives in the small intestine of man, less commonly in dogs and cats. Geographically, it is met with mainly in Russia and Sweden, but occurs also in Switzerland and other parts of Central Europe. It is known also in Turkestan and in Japan, as well as in the island of Madagascar and in the lakes region of Central Africa.

Infection in man takes place through the eating of raw or imperfectly cooked fresh-water fish, notably the pike. Dibothriocephalus is one of the longest of tapeworms, sometimes reaching thirty feet in length. The body is greyish-white, flat and tapelike, and consists of a chain of distinct joints, of which in very complete examples there may be as many as four thousand. The main significance of the continuous production of joints or segments lies in the fact that when mature they liberate many thousands of eggs, each of which is potentially another worm.

This tapeworm floats freely throughout its long length in the alimentary canal, and is attached at its original end or "head" by a pair of deep slit-like suckers which grasp the intestinal wall. Growth continues in the region immediately behind the "head." The essential features of a tapeworm of this stage are: there is no food canal; feeding takes place by the simple process of absorption of the already digested food of the host; the worm's body is encompassed by a resistant cuticle, and it cannot be digested by the secretions of the host; and, as already mentioned, prac-

tically the whole length of the worm is given over to the production of fertilised eggs which pass from the host's body to the exterior.

Further development can take place only if these liberated eggs reach water in which certain minute freshwater Crustaceans are living. These are of the same order as Lernæa, but free-living, not parasitic. They are very similar to the common "water-fleas" familiar in our ponds and ditches. From the Dibothriocephalus egg when it reaches water there soon emerges a minute spherical body covered with cilia by means of which it swims, it may be for days on end. Eventually, if fortune favours, the free-swimming stage is swallowed by a water-flea of the genus *Cyclops*, or *Diaptomus*. It is not killed, but progresses a stage further in its eventful history. If luck still holds, the water-flea is in turn gulped down by a pike, or failing that, a trout or other fish. Here the larval tapeworm (technically called procercoid) becomes active, and freeing itself from the body of the water-flea, it bores its way to the flesh of the fish and a further stage of development is reached (technically called plerocercoid). Here the parasite remains permanently

unless the flesh is eaten by man—raw or imperfectly cooked. In such a case the plerocercoid larva becomes active; by means of a pair of muscular suckers it attaches itself to the intestinal wall of the newly-found host, and by a process of growth the adult condition is in due course reached. Segments continue to be produced indefinitely from which an unceasing liberation of eggs takes place, some of which by lucky chance will carry on the life of the species in a fresh succession of hosts.

Reviewing the main facts, we see that three different animal types are involved as hosts, in the course of the life-history. Such a complex undoubtedly limits the numbers which can complete the life-cycle, and there is no doubt that the chain is more frequently broken than otherwise. But the manifold risks of failure are met by the extremely prolific character of the tapeworm. Manifold risks indeed, for many eggs never reach water at all. Of those that do, many never encounter a water-flea. Most water-fleas probably escape the voracious pike. Only in certain quarters are pike eaten by man, hence the rather localised distribution of this parasite, and this is fur-

ther limited by the cooking of the fish. Yet in spite of all these vicissitudes the Broad Tapeworm, *Dibothriocephalus latus*, is still with us.

But while this is so, man is gaining ground, and human tapeworms are decreasing in numbers. It is safe to say that with the spread of knowledge man's ways of living are becoming more hygienic and tapeworms are already doomed to extinction amongst civilised peoples.

ANKYLOSTOMA OR HOOKWORM

The group of round worms or Nematodes includes numerous parasitic species, exhibiting great variety of habit and life-history. Amongst them is included the important parasite known as the "hookworm." Although known for a long time previously, it first attracted serious attention in an outbreak of disease amongst the miners engaged in the construction of the St. Gothard Tunnel. Owing to its prevalence amongst miners and other workers in the earth it is still known as the "miners' worm." This creature, scarcely half an inch in length, and about the thickness of a stout thread when adult, inhabits the small in-

testine of man. It is armed with hook-like teeth, by means of which it adheres to the glandular covering of the bowel. At the place of attachment the tissue is broken down, bleeding may take place, and beyond the mechanical injury the parasite has a poisonous effect upon its host. The seriousness of an infection depends in some measure upon the numbers present. Profound changes in the blood ensue from the presence of these parasites and these result in a specific bloodlessness or anæmia which continues as long as the parasites remain undisturbed. Owing to the possibilities of repeated infection, the numbers present in an individual man may be huge, and infections if untreated may persist for many years.

A notable feature of the biology of this parasite at the present day is its extreme commonness over vast areas of the globe. Throughout the tropical and subtropical regions of the earth, over an area within which more than half the world's population is to be found, there are hundreds of millions of human beings living in a state of greater or less physical and mental debility owing to the presence of this worm within their bodies. What is the life-history of this remarkable hook-

worm parasite? Where infection is common the sanitary provisions are always unsatisfactory. The eggs are voided into soil or water. Here under suitable temperature conditions development proceeds, and there emerge microscopic larvæ which spend a brief period of free life in water or moist soil, during which they undergo certain structural changes. They reach a stage when, if they come into contact with the human skin, they straightway burrow in. Penetration usually takes place through the feet or ankles, but it may be effected through the mucous lining of the mouth or throat, in the event of the microscopic worms being taken in with food or water. Soon after they penetrate into the body they enter a lymphatic vessel or a vein, pass onward with the stream of lymph or blood, and eventually arrive at the venous or right side of the heart. From here the journey is continued to the lungs. And now, after this period of passive transportation, they continue their travels on their own account. Burrowing from the blood vessels to the air passages of the lungs, they actively work their way along the bronchi and windpipe until, having arrived at the throat, they now turn backward

along the gullet, passing through the stomach to that part of the intestine in which they become mature. Here they attach themselves by their hooklike teeth, commence feeding upon the glandular tissues and blood, and eventually become mature. The females now start upon a spell of egg-laying, the eventual result of which, under circumstances favourable to the parasite, such as soiled hands or feet, or contaminated food or drink, is the infection of fresh individuals or the re-infection of already existing victims. It ought to be added that treatment when the disease is diagnosed is easy and effective. All that is lacking for the control and eventual elimination of this human scourge is adequate organisation, especially the avoidance of fouling the soil indiscriminately or of walking with bare feet on soil that has been fouled. Notable amongst the Institutions which to-day are active in enlightening affected peoples as to the nature of this parasite and its mode of entrance into the body, as well as in treating patients, are the public health services of the United States, the Colonial and India Offices of Britain, and the French and Dutch Governments.

When we review the agencies concerned in the linking-up of parasites and their hosts, as revealed in the examples already described, we see how great a part is played by casual external media, notably water. A wider survey, which is not possible here, brings to light other fortuitous agents such as wind, chance contamination of food, contact with individuals already affected, and so on. Besides these, however, there are linkages between parasite and host which are dependent upon definite associations between hosts of the same parasite, so that there intervenes no stage in which the parasite is free-living, either in an active or passive phase. The best examples of this kind of relationship are met with in cases where one of the hosts is a blood-sucking creature, such as a leech, insect, or tick. The details of such an association are illustrated in the following example.

FILARIA NOCTURNA: A PARASITE OF MOSQUITO AND MAN

This is a minute threadworm or Nematode not uncommon in the blood of human individuals in the tropics of both hemispheres. The term

Filaria refers to the slender threadlike form which is characteristic of the genus, and this particular species is designated *nocturna* from the fact that it is present only at night in the blood circulating at the surface of the body. Early in the evening these microscopic creatures coming from the interior of the body begin to appear in the blood vessels at the surface, their numbers gradually increasing until about midnight they are so abundant that as many as five or six hundred may be obtained in a small drop of blood drawn from the finger-tip. After midnight the numbers gradually decline, until by early morning they have practically disappeared from the surface circulation. Investigations have shown that in the daytime they are hidden away in the large vessels and in the more deeply situated organs, such as the lungs. It has been estimated that a single individual may harbour as many as forty millions of these minute embryo-worms, and yet be unaware of their presence as far as symptoms of any description are concerned. In a proportion of cases, however, there are disease symptoms of a repulsive and distressing nature, such as the condition known as elephantiasis (marked, for instance, by

thickening and coarsening of the skin), but this does not appear to have any direct relation to the forms swarming in the blood, which are all immature creatures. The adult worms, which may be limited to a few pairs, live in the lymphatic system, and the diseases referred to are more directly associated with them.

The clearing up of the details of the life-history of *Filaria nocturna* marked a most important stage in the increase of our knowledge of blood-inhabiting parasites, for it afforded a clue to other problems, in particular two important diseases affecting the human race, namely, malaria and yellow fever. The clearing up of the Filaria life-history, which we owe to the late Sir Patrick Manson, ranks of the highest importance in medical science, for it was the first case in which the action of a mosquito in disseminating parasites in the blood of man was demonstrated. Manson found that the periodic appearance of the young Filariæ in the peripheral blood at night was correlated with the night-biting habit of certain mosquitoes, and further that the mosquito plays a specific and not merely a casual rôle in the life of the parasite. The young stages of *Filaria noc-*

turna are ingested by the mosquito in the act of imbibing blood from its human victim; they reach the insect's stomach, bore through it and pass to the muscles of the thorax. Here they grow rapidly in size while internal development proceeds. They slowly progress forward along the thoracic muscles and pass through the tissue of the labial or under-lip sheath which guards the piercing stylets used in blood-sucking. When another human victim is attacked by the infected mosquito, the pressure of the labium, congested with numbers of Filariæ, causes it to rupture in the immediate vicinity of the wound, the parasites are released and enter the body by the perforation which has been made. Thus a fresh infection of a new host is established. The introduced Filariæ now enter on a fresh development and finally reach the adult condition. The adult females, which live in the lymphatic vessels, in due course liberate not eggs, but young Filariæ, which are the forms with which our description started. Such a life-history has been laid bare only by much patient investigation and scientific insight. The facts have been abundantly verified, and in affording clues to the elucidation of other

important relations between man and his parasites they have proved of supreme value to mankind.

PARASITIC PROTOZOA

Amongst the Protozoa or unicellular animals there are numerous species which live within the bodies of other creatures. Many of these are not true parasites; they do not feed upon the substance of the host, but upon the contents of the food canal. Yet the relationship is not of a casual nature, since such forms may be restricted to this particular situation in particular species. There is, for example, a very definite Protozoon fauna of the alimentary canal of many creatures, *e.g.*, the common frog and insect larvæ generally; indeed probably most animals of suitable organisation possess an intestinal fauna which occurs nowhere else. Doubtless in the lack of complete knowledge of the lives of many of these it is impossible to say whether or not they are true parasites. Some are probably commensals, benefiting the host in some way. On the other hand, we know that two closely related species may live in

the same situation, one of which is harmless, while the other is undoubtedly parasitic and pathogenic (that is, disease-causing) as well. This is the case with regard to two closely related amœbæ which are found in the human lower bowel. One of them, called *Entamœba coli*, lives upon the bacterial inhabitants of the intestine, but the other, called *Entamœba histolytica*, lives upon the cellular lining of the intestine, penetrating beneath it, actually ingesting red blood cells, setting up ulceration, and producing a characteristic dysentery. The doubt in regard to the exact rôle of Protozoon inmates of the food canal does not apply to those found in other situations. Some find a habitat in the liver (Coccidium), another in the spleen (Leishmania), another in the body muscles (Sarcocystis), still another in the heart (Schizotrypanum), whilst in the circulating blood itself various important parasitic organisms find a home. Some of the best known of these occur within man himself, and exhibit very remarkable biological inter-relations. Microparasites of the blood of Vertebrate animals are associated with an intermediary host in the form of an animal of blood-sucking habits. For aquatic

hosts this is usually a leech; for terrestrial animals a blood-sucking insect or tick serves as the connecting link.

As regards the human race it may safely be asserted that no inter-relations between man and animals have been of greater significance than those which relate to certain parasitic animals which find their normal habitat in his blood. It is sufficient to mention such diseases as sleeping sickness, yellow fever and malaria; these are problems of parasitology whose complexities have been in the main unravelled. There are others, such as kala azar and typhus fever, whose life-histories are not as yet completely understood.

While this is not the place for discussing these diseases, it is appropriate here to consider some of the biological problems which are involved. And no better example can be taken than that illustrated by the life-history of the organisms of malaria.

THE MALARIA PARASITES OF MAN

These blood-inhabiting Sporozoa of man are introduced to his circulation by infected mosqui-

toes of the Anopheline type when these are engaged in "biting." In the act of blood-sucking these insects introduce fluid from their salivary glands, and in this secretion extremely delicate, short and slender active organisms are swarming. These organisms are the infective stage of malaria parasites. When thus introduced into man's circulation, each individual attaches to a red blood corpuscle and passes within it. Here it assumes a rounded or globular form, absorbs nutriment from the cell-substance, increases in size, and by a process of division breaks up into a progeny of from about eight to twenty, within periods ranging from twenty-four to seventy-two hours. The difference in numbers and periods of time mark different species, of which at least three are known. In every case the affected blood cell is destroyed by the intruder's multiplication. The young forms resulting from growth and division in turn attack fresh blood cells, and the destructive cycle is repeated. By this geometric increase the numbers of blood cells which are destroyed mount up rapidly, and after a time the presence of the parasites becomes apparent by the onset of those periodic rigors which

are characteristic of malaria fevers, and which are associated with the periodic breaking-up of blood cells and the release of the broods of parasites. It is estimated that there are about twenty-five billion red corpuscles in the blood of a normal adult man. Sir Ronald Ross has stated that a twelve per cent. infection constitutes a highly severe one, *i.e.*, one involving about three billion cells at the moment. While this is so, 250 million parasites may be present without causing any great inconvenience. While the parasites are slowly growing within the blood cells, regeneration of new blood cells may for a time keep pace with the losses; yet without treatment, even in the more benign forms of the parasite, anæmia and other complications early result.

For a time all the parasites which grow in man's blood are alike, but eventually certain forms arise which are different in their nature and which do not divide. In the event of the malaria-affected individual being bitten by a suitable mosquito, numbers of these new forms are drawn off with the imbibed blood into the insect's stomach. Unless this happens the life-cycle remains uncompleted. The new type of parasite

is really a sexual form, and in the stomach of the mosquito there results from sexual union amongst these a freely motile fertile cell which passes through the stomach wall and forms a cyst upon its outer side. In this cyst thousands of the type infective to man are formed. Eventually through increase of numbers the cyst is ruptured and the parasites set free into the blood cavity of the mosquito. There may be many such cysts in a single mosquito, so that the number of its parasites may be exceedingly great. These pass within the mosquito to its salivary glands, which are in direct communication with the piercing stylets which penetrate the skin when the insect is in the act of feeding. Saliva passes into the wound during the process, and in such a case as we are considering it is richly charged with malaria parasites. Thus is the life-cycle completed, and the continuance of the malaria organism is assured.

GENERAL CONSIDERATIONS

The foregoing illustrations of parasitic life, few in number and admittedly inadequate to represent the whole field, may yet serve to reveal

some of the inter-relations amongst living creatures which lie out of the way of common vision. The examples which have been given are really representative and not exceptional instances of parasitism. We must now direct our attention to a more general view of the subject.

It will have been noted that the degree of intimacy between parasite and host differs considerably in different examples. There are ecto-parasites, those which infest the exterior of the body of other creatures. These are of two kinds, roving and sedentary. The most notable of the former are the body lice of birds and mammals. These are specialised mainly in two ways, viz., in the flattening of the body, and in the development of particularly effective claws for clinging to fur or hair. Such creatures feed on the skin products or suck the blood. Sometimes there are more complex inter-relations, as, for example, in the case of the body louse of man, which is now known to be the means of transmitting typhus fever and European relapsing fever from man to man. In the course of the recent European war it was also shown to be the transmitting agent of the virus of trench fever. Amongst sedentary

forms are the flat Helminths or flukes which attach themselves to the skin of aquatic animals, *e.g.*, the skin or gills of fishes. These do not differ greatly from their free-living relatives, the Turbellaria, except that they have lost the ciliated covering of the body, have acquired a cuticular one in its place, and have gained sucking discs for adhesion. They feed on the secretions of their hosts, and it is interesting to compare them with the Temnocephalid worms which cling to fresh-water animals. These are not true parasites, since they feed on small Crustaceans, worms, and the like which live freely in the water.

Amongst Crustaceans many interesting forms occur, showing transition stages from the external to the internal type of parasitism. The Isopods or "fish lice" are mostly external parasites, but amongst these we find some which live in cavities below the surface although they remain enveloped in a fold of the integument. Some of these have root-like absorptive outgrowths for feeding. We have seen how in a case like Sacculina there is a transition to internal parasitism, and how an entirely new body is developed with no traceable resemblance to the old one.

Endoparasitism is, however, evolved in other ways. The open passages of the body afford opportunities to creatures of varied organisation, and many enter in which do not live there as parasites. Besides alimentary canal inmates we may note some forms of the higher Crustaceans (Decapods) which inhabit such situations as the mantle cavity of molluscs, the water-canals of sponges, and the "respiratory trees" of sea cucumbers. It is probable that in many cases what began in the discovery of sheltered haunts, and profitable haunts as regards food-getting, gave rise to true parasitism. The parasites of the respiratory tubes of certain insects, *e.g.*, the mites causing acarine disease in hive bees, may in the first instance have simply sheltered there, and later developed the habit of feeding and remaining to breed. Where complex inter-relations between different hosts have been established, the evolution of such life-histories remains for the most part very obscure. It seems probable that in the case of blood-inhabiting Protozoa and the threadworms of Vertebrates, the parasite was originally an inhabitant of the intestine of the Invertebrate host.

It is not easy to explain how intestinal worms

evolved the habit of reaching the alimentary canal via the skin and circulatory and respiratory channels, nor why some, as in the case of the common threadworm of the pig in its early stages, in passing along the alimentary channel, should turn aside, and boring through the stomach wall perform a migration through liver and lungs to return to the throat, whence it traverses for a second time the pathway of the gullet and stomach on its way to its normal haunt as a mature individual, the small intestine. It would be fantastic to suggest that all this is merely "wanderlust" of youth. We may recall the fact that worms of this class (Nematoda) have muscles composed of cells of quite distinctive structure, and that restlessness or a disposition to wander is a common characteristic of the group. Yet the connection may not be very close, and we are compelled to accept the facts as one more instance of intricacy not yet unravelled.

Little has been said regarding parasitic insects. Those living on the surface of the body of Vertebrates are legion, yet relatively few in number in comparison with those which live within the bodies of other insects. There are whole families

belonging to the higher orders, Hymenoptera and Diptera, whose larval life is spent within the bodies of other insects, and which serve as a check on the increase of the host species, since it is but rarely that the parasitised individuals survive to reproduce their kind. Such larval parasites are usually simplified in structure, befitting their habitat and habits, yet they invariably give rise to adults, which are winged, free, and well endowed with specialised sensory equipment and instinctive capacity for finding their appropriate hosts, in which to implant their eggs or their young.

But with the illustrations already given in detail we must be content. Rightly understood they indicate the place in nature of the parasitic animal. They show us, on the one hand the success with which the security and comfort of the individual are maintained, and on the other the surmounting of the ever present menace to the race in the difficulties of transference of each new generation to a fresh host. The intricacy and variety of life-story of parasites at many different levels are but illustrations of nature's resourcefulness under exceptional difficulties in meeting those fundamental needs of living which parasites share in common with other creatures.

Chapter V

Communities and Partnerships Among Plants

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Chapter V

Communities and Partnerships Among Plants

WE fulfil the law within us when we say, "The proper study of mankind is man." But we do not mean what Pope meant, for the poet found his material in man alone and merits Macaulay's judgment of Johnson, that would-be critic of society: "He knew not the genus man, only the species Londoner." And students of man merit the same censure if they pigeon-hole humanity and refuse to study it against the background of other living creatures. For a knowledge of life as a whole enables the student to focus the larger light upon any part and show it up more brightly illuminated. Thus equipped we see man's life widened and deepened.

In a brief essay it seems most profitable to limit our illustrations of the laws governing the communal life of plants to a study of two kinds of association: partnerships between plants where

the advantage is believed to be more or less mutual, and communities of plants where varying kinds of inter-relations co-exist—mutual advantage, mutual tolerance, one-sided advantage, and indispensable or obligatory association.

PLANTS AND THEIR ENVIRONMENT

But first let us clear the ground. The study of plant behaviour is much simpler than the study of animal behaviour, for there is here no known complicating instinct or intelligence. On the one hand we have the plant, and on the other the environment—the external conditions. But the study although simplified is by no means easy, for both the plant and the environment are exceedingly complex.

Everyone who has anything to do with plants, be he gardener, farmer, or forester, knows the intimate relation existing between soil and weather conditions and the production of bloom, of grain, or of timber. These soil and climatic conditions make up the physical and chemical environment of the plant. This, of course, is complex and varies from hour to hour, season to

season, and year to year. The sunshine received, the temperature of air and soil, the amount and seasonal distribution of rainfall, the food materials, whether applied artificially as manures or present naturally in the soil—all and many more *factors* of the environment influence the growth of plants. Some of these factors may be definitely hostile, so that lime is added to assist the growth of kidney vetch, or acid peat is provided to enable some rhododendrons to grow. Other factors are present in insufficient quantity, so that, in our climate, palms and vines are grown in hothouses. Thus we are introduced to the fact that the plant can maintain itself under certain (and varying) conditions, provided these do not pass beyond certain limits. For example, the plants of our temperate zone are in general found neither within the Arctic Circle nor within the tropics; killed by cold in the one case, they live too fast a life in the other and die without reproducing. For to be successful in life a plant must be able to maintain itself, grow and reproduce, otherwise it is classed among the unfit to which the privilege of parentage is denied. Factors of the environment, therefore, may be present in

excess or in defect, in both cases failing to enable the plant to pass the test of success.

NEED FOR NITROGEN

Of the many substances required by plants, nitrogen is one of the most important, as all who cultivate plants realise. This substance forms the bulk of our atmosphere and is present in great abundance in our peat-bogs and heaths. Yet most plants cannot grow in these soils, and they cannot make use of the nitrogen in the form in which it occurs there; for the seed-plants as a class only use nitrates, and cannot avail themselves of the nitrogen offered as atmospheric nitrogen or combined in complex organic compounds in the peat-bog. Yet the pine and beech and heather grow on our heaths and pass the test of fitness demanded by Nature. How have these plants effected the conquest of such inhospitable soils?

ROOT AND FUNGUS

If the roots of a beech grown on a good loam be examined, they are found to show the normal

structure at their tips. This consists of a root apex without any root hairs; these arise, some little distance further back, from the superficial root cells. These root hairs are in intimate contact with the soil particles, and through them pass the water and minerals taken up by the plant. In the beech rootlets from a heathy soil we find something quite different. There are no root hairs, but there is a closely interwoven felt fitting like a garment over the numerous stumpy rootlets. Hair-like threads radiate outwards into the soil, and they also grow inwards, pushing their way between the cells of the superficial layer and the cortical cells. It is clear that this felt replaces the root hairs, and through it pass the necessary water and salts. An intermediate condition linking up the two extremes is found in roots from some soils, where both root hairs and this felt are found in the same root system.

The mantle of threads round the rootlet is composed of the interwoven hyphæ of a fungus, and the association of fungus and root is called *Mycorhiza*. A similar state of affairs is found in the pine, which has poorly developed mycorhiza in good mould and well-developed in raw acid

humus and in drained peat. Here again the fungus replaces the root hairs in the acid soils. What then is the exact relation between the tree and the fungus?

That the fungus is not essential to the existence of the tree under all circumstances is clear, for it is not always present; and its occurrence is often casual. But it is absent or poorly developed in just those soils where the readily available nitrates are abundantly formed; and it is well developed where there is plenty of nitrogen in some form, but little or none as nitrate. It is believed that the fungus (and many bacteria and fungi share this property) is able to make use of the complex organic nitrogenous substances in the partially decayed plant remains of heaths and peats, passing them on to the tree, which thus benefits by the association. It is even stated that the pine cannot survive on drained peat without the assistance of a fungus. For in heathy soils there are many micro-organisms making use of the available nitrogenous supply, and perhaps the tree roots are of themselves unable to compete successfully with these. But the fungus of the mycorhiza is able to do so and the tree shares in

the spoil. In return for the nitrogen the fungus receives sugar from the tree. It must not be supposed, however, that this simple exchange is the whole inter-relation between the two plants, for some of the fungi at least do not fruit away from their partners, and in the pine and spruce mycorhiza the fungus perhaps receives the stimulus necessary for its normal growth. The bonds uniting tree and fungus therefore vary in strength: at the one extreme an independent tree, at the other a tree wholly dependent for its survival on partnership with a fungus. The beech and the pine and presumably many others seem to have extended their range to less hospitable soils through the assistance of certain fungi.

THE HEATHER'S PARTNER

Degrees of dependence existing contemporaneously in the pine afford us some clue to what may have happened in the heather, whose seedling development at least is wholly dependent upon the infection of the seedling by a fungus. As everyone knows, the ling can grow on very infertile soils—heaths, moors, and wet peat. It is

a masterful plant, successful probably because it has few competitors or because it is not too fastidious. And yet it is not one plant but two, an association so intimate that parts of the one were overlooked until some years ago, when it was found that a fungus not only grew in the roots but extended through the whole plant body, through the stem and leaves and out into the ovary—the cradle containing the ovules or seeds, which include the embryo plant. When the seed is shed, fragments of the fungus adhere to the seed-coat; they penetrate the radicle of the germinating seed. There the hyphal threads grow into the cells of the roots and also form an external network, as in pine and beech. But the association of fungus and heather is much more intimate than in these trees, for without the aid of the fungus the young ling plant never survives babyhood. Here again the fungus is believed to cater for the nitrogenous needs of the ling in a soil hostile to the formation of nitrates; the fungus receives in exchange certain carbon compounds, such as sugar.

PARTNER BECOMES PARASITE

Under normal circumstances the "balance of profit" is believed to be with the ling. But the balance between fungus and higher plant is one of great delicacy, for if an external factor prevents the normal development of the heather, lowering the vitality of the plant, then the partnership is dissolved and the relation reverts to that of parasite and host, the fungus luxuriating in the plant cells and bringing about their disintegration. The relative poise or stability of a dual organism of this kind is conditioned by external circumstances, a disturbance in which shifts the fulcrum and upsets the balance; one or other partner becomes dominant and the condition of mutual advantage passes over to one of parasitism.

Here the fungus becomes parasitic on the higher plant, but examples occur of the reverse relation, for in the colourless bird's-nest orchid and coral-root the higher plant is dependent on the fungus or may be considered as its parasite. A similar case is found in a colourless Japanese orchid (*Gastrodia elata*), which parasitises the

honey fungus which causes disease in potato tubers and also plays havoc in the woodlands of this country.

This brief traverse of a series from casual association of fungus and higher plant to a partnership in which one partner is dependent on the other, demonstrates the varying relation between the two organisms. In fact each association must be studied by itself to discover what the partnership really amounts to; and an interrelation or linkage may vary with external circumstances.

The associations we have mentioned result in a new synthetic unit, an association of two unequally endowed plants: one a colourless filamentous obscure organism dependent for its food on living or dead plants, the other a higher plant which in general can build up from the carbon dioxide of the air and the simple salts of the soil, highly complex sugars, starches, and nitrogenous compounds. This synthetic organism yields more than the sum of the activities of the two individuals acting separately. It is a case of two and and two making more than four, this strange arithmetic being expressed in the extending

mastery of the new unit over external conditions, hitherto hostile to one partner at least. Of course in this so-called partnership there is no conscious working of one partner for the benefit of the other; each plant is all out for itself. There is no altruism here; the law of competition dominates in the plant world.

PLANT SOCIOLOGY

We pass now to the consideration of a unit of a different kind, demonstrating very diverse inter-relations between the organisms comprising it. This unit is *the plant community*, the subject-matter of plant sociology, which is a comparatively new study and much less familiar than the study of societies of animals. A comparison, therefore, with the animal community will serve to introduce the point of view.

Students of social animals (of which man is the chief) find analogy with the individual organism profitable, and make a parallel between the central nervous system and the executive body—the cabinet and parliament of a nation, or the Lord Provost and magistrates of a city com-

munity. The various organs of the body, each contributing its share to the well-being of the whole, may be compared with the various groupings of individuals drawn together by "community of occupation, of profession or business, of religion, of interest or opinion, or even of taste," and these organisations, societies, or clubs play a part in the economy of the national or civic unit just as do the organs of the body. Even the most characteristic attributes of the organism, its power to grow and reproduce, are also features of the human community. The passage of a city-state to an empire illustrates both attributes, for more are produced and survive than can live with reasonable comfort within the limits of the original community. The city extends its boundaries, that is to say, it grows; or emigrants settle in new areas and reproduce with extraordinary faithfulness the characteristics of the parent unit. Think of the Greek colonists reproducing their parent cities in Syracuse, Naples, and Marseilles, and of the Romans of a later date carrying their *lares et penates* with them to the bounds of their empire; or in recent times of the settlers in New England, whose modern representatives, despite

the influx of different nationalities, form a nation still recognisable as the offspring of England. That like begets like is true of communities as of individuals.

What then of the plant-world? Have we here only to reckon with individuals or have we units of a higher order, definite associations of plants recognisable as the same in different places? The plain man has answered this long ago, for the common names of marsh and heath and moor and forest express the fact that plants do grow in definite groupings, and that these are recognisable when referred to by common and not proper names. But how far is it possible to compare these groupings or communities to an individual organism? Have they, like organisms, a definite organisation? Can we trace their origin and discern phases of youth, middle age, and maturity? Do they reproduce themselves and extend their boundaries? Let us then put these questions to Nature and seek justification or condemnation of this philosophy in a study of the development and life-history of the forest, one of the commonest and most highly organised of these plant communities.

THE FOREST COMMUNITY

From among the many different kinds of forest let us select beechwood, which perhaps attains its finest development on the chalk hills of the Sussex Downs. Clothing the Downs there is a mantle of green springy turf replaced over large areas by woody vegetation presenting to the untrained eye an orderless panorama of forest. Here there are beechwoods, ash-oakwoods, and extensive areas of a scrub consisting mainly of hawthorn and blackthorn. Can we detect any order here or is it simply chaos? In the first place it is not chaos, for we have already distinguished grassland, scrub, and woodland—definite groupings of plants recognised by the plain man. But are these communities linked together in any special way, or are they quite independent units without developmental ties? Do they occur in definite order, or are they mixed up anyhow? From a point of vantage let us view the panorama and with the eye traverse the ground from grassland to beechwood—grassland, scrub, ash-oakwood, beechwood. With some exceptions the same sequence is observed throughout the area.

Here then is our first discovery, our first thrill, for the human mind delights in discerning order in apparent chaos, and also in seeking out the answer to its own inquisitive why.

INVASION AND SUCCESSION

Chalk grassland has from very early times been used as sheep walk, and where the grazing is moderately heavy the only plants that survive are grasses and those herbs that can withstand persistent cropping or are disliked by grazing animals. To this grassland the wind blows seeds and fruits with various contrivances that render them buoyant; the feathery fruit of clematis, the parachuted seeds of dandelion and hawk-weed, the strap-like fruits of ash. Birds drop the heavy acorn from their beaks or void the seeds of sloe, bramble, honeysuckle, and yew, whose fleshy coverings prove an attraction. These and many more fall on the soft turf, but out of the many some never germinate, some germinate and die, whilst relatively few germinate, survive, and become established. But although these few have run the gauntlet of numerous foes, success,

measured in the world of organisms by permission to reproduce, is not yet assured; for unless they are unpalatable or able to withstand persistent nibbling by sheep and rabbits, they are unable to continue their kind. Thus whilst moderately heavy grazing continues, grassland with the aid of the battening flocks remains unassailable.

FROM GRASSLAND TO SCRUB

We understand, then, the conditions that determine whether newcomers will be able to establish themselves in grassland. Should the pressure of grazing animals be relieved, for example, by a fall in the price of mutton, by the replacement of sheep by the more fastidious cattle, or by a decrease in the number of rabbits, then of the plants which have found a foothold some have a chance of escape, particularly those with some equipment protective against browsing animals. The seedlings of the ash, oak, and beech, having no such equipment, must disappear; only those plants survive that are distasteful to grazing animals or are protected by spines from their too harmful attention. Thus the spiny haw-

thorn and blackthorn, bramble and rose escape, and the scrub community is definitely initiated.

The vegetation now develops as if by its own momentum, for scrub is less hospitable to browsing animals than grassland, and where a choice is available, the grassland is preferred. The hawthorn and blackthorn increase in size and form clumps; these clumps fuse, and in fusing exterminate by the shade they cast the enclaves of grassland. Thus a scrub is formed which is penetrable with difficulty.

LAW OF EQUILIBRIUM

In the foregoing we have an illustration of that "universal law of equilibrium which governs all the processes of which we have any knowledge, from the movements of the planets to those of molecules, atoms, and electrons, from the activity of protoplasm to the vagaries of the human mind." The grassland is in a position of balance or relative poise with the environment, but a disturbance in the environment, namely, the partial lifting of grazing pressure, renders the vegetation unstable and leads to a fresh activity tending

towards the establishment of a new equilibrium, namely, that of scrub. A disturbance in the opposite direction, an increase in the severity of animal attack, leads again to the establishment of a new equilibrium, this time in the reverse direction.

FROM SCRUB TO WOODLAND

On the removal of the factors which prevented the establishment of the unprotected spineless plants, seedlings of these become established; but lest we may become entangled in the undergrowth of detail, let us keep to the three trees ash, oak, and beech—the trees which dominate in the next two stages of this succession, namely ash-oakwood and beechwood. What determines the order of their occurrence? Why should the ash-oakwood precede and not follow beechwood? It is a race between three competitors, so let us study the points of the runners.

Compare the mobility of the seeds. The ash has a long strap-like fruit, which when detached from the parent revolves rapidly, thus decreasing the rate of its descent. This allows the wind to

act for a longer time on it than if the seed fell precipitate to the soil. The glossy dark brown acorns are heavy, but rooks are fond of them, carrying them for longer, but chiefly for short distances from the parent oaks, and finally alighting on the ground to peck at them. The three-cornered beechnut is much smaller and swallowed whole by pigeons near the parent beeches where they find them. The order of mobility then is, first the ash, then the oak, and, a good way behind, the beech.

Mobility is one factor, but there are others affecting numbers of individuals and rate of progress. The length of the life-cycle from seed to seed is obviously of importance, and the tree which reproduces early in its life has, other things equal, an advantage over a late-reproducing rival. And if this power is combined with more frequent and more abundant seed production, then the advantage is considerably increased. In this case the ash produces seed earlier, oftener, and more abundantly than the oak and beech; the oak oftener than the beech and both at longer or shorter intervals. Thus in this invasion of scrub, there is, as a result of qualities inherent in the

trees themselves, a fractional distribution of woodland—in front a zone of ashwood followed by a zone containing many oaks, while well behind there is the beech.

OAK AGAINST BEECH

Let us now suppose that a halt is called to the advance of ash owing to the lack of more protective scrub, then the speed, mobility, or the power of the ash to get out of the way of competitors can no longer be exercised. Its back is to the wall and it has to compete with its oncoming rival the oak, for the beech is still well beyond effective striking distance. Here we are introduced to another factor in the competitive equipment of these trees. It is well known that some plants can grow under the shade of other plants, and we call these shade-bearers. Others are intolerant of shade and die or continue a half-hearted sort of existence when cut off from the direct rays of the sun. To the former class belongs the beech, which is a very pronounced shade-bearer; to the light-demanders belong both

ash and oak. But between these two there is a difference, for oak can endure more shade than adult ash, and it is this power which enables the oak to make its way into and establish itself in the ash zone in front. A period of struggle follows, the oak continues to increase numerically, the ash to decrease, until a halt is called by the environmental factors. Finally, after passing through a stage of youth when the ash is comparatively secure against competition, through a stage of immaturity when the conflict of ash and oak is severe, a stage is reached when the environmental factors determine the relative proportions of the two trees in the mature ash-oakwood. The struggle in the canopy is reflected in the undergrowth. Tangles of living, dead, and dying hawthorn and blackthorn point to the intense struggle, however peaceful and tranquil the battlefield may appear to us. The unfit—those which cannot compete successfully in the new environment—are ruthlessly exterminated and other species conforming to the new conditions take their place. Thus is born the beauty of natural ash-oakwood with its shrub layer of hawthorn and bramble,

or privet and blackthorn, and its carpets of green mercury, its beds of wood violets and its sheets of wild hyacinths.

But what of the beech, the tortoise in the race? Its weak point is its immobility, its strong point is its tolerance of shade; and it is this quality which enables the invading beech seedling to grow up into the beech sapling under the shade of ash and oak. Arrived at maturity the beech sheds its seeds and some of the offspring survive and in turn become parents—the whole group of grandparents, parents, and children forming what we may call a family which slowly but surely extends its boundaries at the expense of the ash and oak, for these cannot succeed under the shade of the beech. The separate families established in this way gradually come together and unobtrusively but relentlessly close in upon their rivals. One remembers Edgar Allan Poe's tale of the Spanish Inquisition, where the heretic is thrust into a chamber with a deep well in the centre and with movable walls which slowly converge, pushing the shrinking, huddled figure towards the brink, while the eyes of the rival, powerful and also relentless, peer through a slot high up on the

wall. It is the law of competition, which when applied with full force in the world of humanity, is to us awful in its severity and relentless tenacity. This law dominates in the plant world and in accordance with it ash-oakwood gives way to beechwood.

It is now clear that the plant population discussed is not simply a chance collection of species; it is not arbitrary, for order is discernible. These plant communities are conditioned by certain factors and obey laws governing their origin, maintenance, and fate. In short, they behave as units, and now we can see the usefulness of a comparison between plant communities and animal or human communities. The plant community exhibits certain activities like the animal community—the power of growth, the invasion and occupation of new territory, and the capacity to reproduce. In the human community the hamlet grows to a village, the village to a town, the town to a city: emigrants invade a new country and after a struggle take possession; and among the colonists we find habits, customs, and institutions (social heritage) similar to those of the country from which the pioneers set out. So

among plants, the plant community extends its borders, invades and overcomes and succeeds other plant communities, and, where conditions are similar, reproduces the characteristics of the original with marvellous faithfulness. But of course invasion in the plant world is not always successful, any more than it is in the human world. In some cases the invaders are defeated at the hands of the inhabitants; in other cases the environmental conditions prove too inhospitable.

The analogy which has so far proved profitable may be carried further in a study of the life-history of beechwood, to find out if there is anything like organisation here, and to discover how such a plant community is maintained.

LIFE-HISTORY OF WOODLAND

For present purposes let us assume that cleared ground has been abundantly seeded with ash and beech and that in the resulting carpet of seedlings there are about twenty of each per square foot (400,000 per 10,000 square feet)—a number by no means excessive under natural conditions. A visit after the lapse of some years reveals what

everybody expects, namely, growth in height and a dense population of young ash and beech. Closer examination shows that the ash has grown faster than the beech, forming a canopy over it, and although the young wood seems still vastly overcrowded, there are only about two saplings per square foot. We thus realise that there must have been an enormous mortality (two left out of each forty plants!), and the numerous dead stems are evidence of this. Here we have illustrated two kinds of struggle, namely, the struggle between members of the same species, beech against beech and ash against ash, and the struggle between different species, ash against beech.

It is well known that no two organisms, even of the same species, are exactly alike. The differences may be insignificant details, but differences of importance to the individual also occur. In a crowded assembly of beech seedlings, some grow faster than others, raise their leaves above those of their fellows, thus securing to themselves the light necessary to their existence. But in doing so they deprive their more slowly growing neighbours of an essential to life, and a sifting

out of the unfit takes place. Thus among these plants which are feeding at the same table and selecting the same dishes there is a keen struggle in which might prevails. A similar decimation among the ranks of the ash occurs, but, inasmuch as each ash requires more light than each beech, the struggle among the ash plants themselves is keener, the mortality is heavier and fewer survive. So that although the two species start numerically equal, by the time they are a dozen years old there are fewer ash saplings than beech saplings.

There is also the struggle between ash and beech, and we have already referred to some factors of the competitive equipment. But here is another not previously mentioned, namely, the ability of the young ash to grow faster than the youthful beech. In this way the ash keeps ahead of the beech, and for a time at least escapes suppression at its hands. But sooner or later the beech overtakes the ash. This may occur when the wood is fifty, sixty, or seventy years old, the exact age depending on the soil factors and the relative suitability of these to the growth of the two trees. At the stage when the beech overtakes the ash, at about sixty, the beech trees outnumber

the ash by about 3 to 1, the total number being now reduced to about 100 per 10,000 square feet. Finally, on the attainment of maturity, when the trees are about 140 years of age, there is only an occasional ash in a wood which starts as an equal mixture of thousands of beech and ash, and which finishes with a practically pure beechwood containing about twenty-two beech stems per 10,000 square feet. Out of the 400,000 only twenty-two survive.

ORGANISATION OF WOODLAND

But a wood is more than the trees; it includes all the plants found within it, the whole forming a unit. The trees, of course, dominate, for they form a canopy—a kind of sunshade—and control the subsidiary flora. Let us follow the effects of this control.

Under the thick canopy of the densely populated young wood, the light is very subdued and quite inadequate for the seedlings of the many mobile seeds carried thither, and although the light intensity increases under the thinning canopy of the ageing trees, seedling herbs do not survive

until (in some woods) the trees attain about seventy years of age. This stage in the life-history of the wood may conveniently be called the Bare stage, since the floor is practically devoid of subsidiary plants.

Among the first to become established at about this age of the wood is the bramble, which survives as a tiny plant about six inches high. But for the present, chief interest is attached to the wood-sorrel, whose numbers are at first small, but later increase until a carpet of delicate green covers the woodland floor. Its chief companion is the wood-violet, but the wood-sorrel remains the most conspicuous until the wood is over a hundred years of age. This stage we may call the Wood-Sorrel stage.

What is the secret of the wood-sorrel's success? Why, out of the many seeds that fall on the forest floor, do those of this plant germinate and produce plants that reproduce? There are many reasons, but the chief are these. First, it can make use of the subdued light of the cathedral gloom of beechwood. No sun-loving plant need attempt to grow here. Secondly, and this characteristic it shares with the wood-violet, it pro-

duces conspicuous flowers before the trees are fully foliaged, and later on, when manufactured food is less abundant, there appear flowers which never open, but which, self-fertilised, produce fertile seed. Thirdly, it produces shoots which travel underground, and it can reproduce vegetatively as well as by seed. A plant which cannot reproduce itself in this environment is unfit.

During the Wood-Sorrel stage the bramble remains an inconspicuous plant, but with a further reduction in the number of trees it grows more luxuriantly, and by the time the wood reaches maturity (or about 140 years of age) it forms a continuous layer. At the same time, consequent upon improvement in the lighting, there is a considerable addition to the number of species found in the Wood-Sorrel stage, and these show adaptations to the prevailing conditions. This final stage in the life-history of the wood we may call the Bramble stage.

There are many other questions that might be profitably discussed if our study of plant communities could be extended; how many plants, such as primrose, anemone, and wild hyacinth, flower early before the trees are foliage clad; how

the roots of the different plants exploit different layers of the soil, the tree roots penetrating to the lower layers, whilst the roots of woodruff and enchanter's nightshade are confined to the upper; and how these different growth-forms—tree, shrub, herb, and moss occupy different layers above ground. These are "unlike commensals," feeding at the same table but selecting different fare.

Such in brief is the life-story of the beech-wood we selected, which starts with millions of ash and beech and finishes with hundreds of beech. We start with a wood with no subsidiary flora and we finish up with one showing a definite shrub layer and ground flora. We find a regular sequence of change, youth, middle age, and maturity, accompanied by increasing complexity from the young woodland with its single stratum of plants (the Bare stage), through the Wood-Sorrel stage with its tree layer and herbaceous layer, to which is added the shrub layer in the Bramble stage of the mature wood. In addition to a life-history we recognise structure or organisation.

The woodland population is thus no indiscrim-

inate collection of plants which have arrived and settled there, no all-inclusive society without an entrance examination, but an association of plants which have passed the test of fitness prescribed by Nature. The candidates for admission are many, but the examining body—which eventually consists of the physical and chemical factors of the environment—makes a rigorous selection, and only the few which can grow and reproduce in the conditions offered are chosen. The woodland flora "exactly fits the mould presented for competitive filling."

PARTNERSHIPS IN THE FOREST

But a study of beechwood would be incomplete without some—necessarily brief—reference to the partnerships found in the forest. The teeming population of the soil attacks and disintegrates the leaves, twigs, and branches that fall on the forest floor, ultimately reducing the elaborated proteins and celluloses to their first beginnings. Here too we find mycorhiza, and in the lichens of the tree-trunks a partnership of an alga and a fungus in which the fungus is the master and

the alga the servant. The trunks of the old beech trees are covered with a mantle of epiphytic mosses, secure in their habitat from the competition of the higher plants but exposed to drought. Their persistence on the bark is an expression of their ability both to take advantage of atmospheric moisture and to resist desiccation during periods of dryness. Here the mosses live perched on the trees but abstract no food from their living parts. Then there is also the one-sided partnership between the climbing ivy and the beech tree, for the ivy clambers up the trunk, holding on by its roots, displaying its foliage in the crown of the tree. Supported by the stem of the beech the ivy leaves compete with the beech leaves and cripple or smother them. Finally, as in some of the tree toadstools, we have the very intimate association of parasite and host, where the former lives at the expense of the living tissue of the latter.

NATURE'S WAY AND MAN'S

Conflicting, depending, and reciprocal interrelations co-exist, but notwithstanding the diversity there is organised uniformity. Yet the

differences between the plant community and the human community are great. There is no "central bureau of nerves" directing and guiding the life of the plant community; there is no awareness among the units of each other or of the community as a whole; there is thus no possibility of corporate life and conscious co-operation for the common weal. We cannot solve Zeno's problem "How to live?" if we try to do as plants do. For we are not plants, neither are we lower animals, nor can we go "back to Nature." It is true that unrestricted competition promotes both health and beauty in the plant world, but to carry out this law in the world of humanity we must first drop from man's estate and become something which is not man. To organise the community along the lines of the forest is to suppress the instinct of human tenderness which is the hope of humanity. What seems demanded of us is to retain in a rapidly changing world the power of adaptability, the secret of the pioneer's success, and to organise according to the genius within, not super-imposing systems from without, however admirably suited to other forms of life they may be.

Chapter VI

Social Animals

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Chapter VI

Social Animals

UNDER this title, used widely, we include those animals in which there is some degree of corporate life, some co-operation and self-subordination, some practice of mutual aid. In a true animal society there is always some integration, some action as a whole, or some combination of numbers to act as a whole, but this climax, as we see it, for instance, in ants, rooks, and beavers, is led up to by an inclined plane in which the social or co-operative trend is clear, though there is no society in the strict sense. We cannot impose hard-and-fast definitions on the subtleties of Animate Nature.

MANY KINDS OF ASSOCIATIONS

In the lower levels of the animal kingdom there are often great colonies formed by asexual multiplication (budding and splitting), in which

vast numbers of individuals share a common life and are physically continuous. Thus there may be many hundreds of polyps making up the colonies known as zoophytes, sea-fans, sea-pens, and reef-building corals. In cases like the Portuguese-Man-of-War the colony is free-swimming and acts as a unity. Thus the transition is made from aggregate to integrate, and the Portuguese-Man-of-War is more of a society than all the multitude of mites in the cavern of the cheese. Some of the free-swimming colonies reach a very high structural level, for the Fire-Flames or Pyrosomes and the long chains of Salps are compound Tunicates which have crossed the boundary between the Backboneless and the Backboned. We see, then, that there may be colonial or corporate life on what may be called a *vegetative* line.

In the second place, passing to societary forms in which the individuals are bound together psychically, not physically, there are many fine instances of corporate or co-operative life on the *instinctive* level. The crowning instances are among ants, bees, wasps, and termites. In these the social organisation may be very intricate.

Thirdly, there are societary forms on an *intelligent* basis, as in the beaver village, the community of prairie-dogs, the herd of wild horses, the troop of elephants, the band of monkeys engaged in plundering an orchard. What seems to us the essential note is the unified action of many individuals, which are certainly not acting on the "each-for-himself" plan. Whether it be the numerous members of a Portuguese-Man-of-War swimming in unison, or the raid of ants engaged in capturing slaves, or the rooks combining against a hawk, or the beavers co-operating to dig a long canal—the social note is struck in *integration* and *self-subordination*.

SOME CHARACTERISTICS OF AN ANT SOCIETY

Many an ant-hill is strictly speaking a huge family, consisting of the children and grandchildren of one queen. But in other cases the ant-hill includes several families, just as a herd of wild cattle or antelopes may include several family groups. It does not seem practicable to draw a line between a large family and a simple society.

What are the salient features of the ant-hill? There is the division of labour, or the development of different castes, the reproductive queens and drones, and the productive (usually non-reproductive) workers; and among the workers there are often several different types, such as soldiers and nurses, foragers, and stay-at-homes. In the bee-hive the workers are promoted through a succession of duties; in the ant-hill a worker may do only one kind of thing all its life. The seamy side of the division of labour and the structurally diverse castes (polymorphism) is seen when the individual is over-subordinated. Thus from man's point of view it is not much of a life to become "an animated honey-pot," an amenable storehouse for the food of the society. The Honey-ants of Texas include these quaint individuals which sink into living jars, and this is a parable full of warning!

Another feature is the strongly developed instinct to be loyal to kin. It looks like kin-sympathy and has doubtless its psychical aspect; but what we are certain of is that the members of a community are quick to recognise one another, probably by smell, and that they are ready and

willing to help one another, and there are certain traditions or conventions which are obeyed like human laws. Thus in some species of ants it seems to be a convention that a full ant must feed a hungry one, if an appeal is made. But the understanding of the behaviour of the children of instinct seems to be peculiarly difficult for inquirers who are in the main creatures of intelligence, so that we are far from being able to explain the extraordinary *esprit de corps* which is often illustrated by the ant-hill.

A third feature is combination in corporate action. The leaf-cutter ants, guarded by soldiers, undertake long marches to suitable trees, and there are pathways in the forest trodden by their tiny feet! While the foragers are cutting off the arcs of leaf, and carrying them home on their shoulders, there are stay-at-home workers who are engaged in masticating previously gathered leaves, and converting them into a spongy paste on which is grown a fungus, the sole food of the ants when they are underground. And this, it must be noted, is but a particularly dramatic instance of the many very remarkable examples of corporate activity in the Lilliputian world. Thus there are

the fierce battles with other species of ants and the slave-making raids. Everyone who has disturbed the hill of the ants in the pine-woods, or even watched the hurry-scurry when a loosely lying flat stone is lifted in the meadow, is familiar with the way in which the nursing-workers immediately seize their charges (the cocoons or pupæ, badly called "ants' eggs") and try to carry them out of danger. How far they know what they are doing is a question for the experts, what one sees is obedience to an instinctive prompting which practically means not "Safety first," but "Save the Children."

A fourth feature in the life of the ant-hill is the storage of reserves. When a severe winter has to be faced, some storage of food is the indispensable economic basis if the society is to last. This is one of the striking differences between the transient summer community of the wasp and the permanent community of the hive-bee. The wasps are carnivores and flesh does not lend itself to storage; the hive-bees store honey, which keeps well. The queen humble-bee has her honey-pot—an often-replenished widow's cruse—from which during her weeks of brooding she gets sustenance

in the cold night or in bad weather, and from which her newly-emerged offspring obtain their first meal; but the tragic difference between the breaking-up of the humble-bee community at the end of summer, only the young queens surviving the winter, and the permanent stability of the honey-bee community is that the humble-bees do not show more than the beginning of storing. This illustrates the survival value of thrift; dare one say of capital? It is interesting to find that there are some kinds of humble-bee that *do* weather the winter, but they live in countries that have no seasons!

As a particular case of storage we may mention the habit that a few kinds of ant have of taking their "milk-kine," the aphids or green-flies, into the underground nest for the winter, tending them somewhat in the same way as man does his domesticated animals. This leads on to those ants that keep fragrant little beetles and other pets, illustrating the beginning of the luxury that the shield of society sometimes permits. A solitary animal may have parasites, but not pets; though there are quaint cases, warning us against generalising, such as the New Zealand lizard or

Tuatara, in whose burrow a petrel lives. They occupy respectively the "but" and the "ben," the lizard to the right, the bird to the left. "Whilst very tolerant of the bird with its egg and young, the Tuatara does not allow another of its own kind to live in the same hole, which it is ready to defend by lying in such a manner that the head is placed where the passage widens out into the chamber."

To return from this picturesque digression, we may sum up the salient features of the ant-community, taken as a type of an instinctive society. The features are: the division of labour, the kin-sense, the communal conventions, the corporate activity, and the storage of food for evil days. In a society of predominantly intelligent animals, the self-subordination and division of labour are less marked, but the general features are much the same.

DIFFERENT SOCIETARY FORMS

There are many different forms of human society, and so it is among animals. Various classifications have been proposed. Thus Pro-

fessor Alverdes distinguishes first of all between the *closed* society and the *open.* In the closed society there is no ready adoption of new members and it is not often that a member can break his allegiance and survive. Moreover, in the closed society there is often an established order of rank or office. Closed societies are illustrated by ant-hills and bee-communities, by beaver-villages, herds of Ungulates, bands of chimpanzees, colonies of prairie-dogs, flocks of parrots, and congregations of rooks.

The open society is less exclusive; newcomers may be accepted; and seceders may pass from one allegiance to another. Many antelopes go in flexible troops, and the same is true of many other cud-chewers. Cranes, flamingoes, pelicans, and many other birds form open societies, and these may be graded according to the degree of their organisation; for instance, whether there are distinct ranks or not. But the facts are hardly secure enough to warrant more than these general remarks on the different forms of animal society.

ADVANTAGES OF SOCIAL LIFE

The difficulties and limitations of life may be met by individualistic effort or by some form of self-subordination and mutual aid. Both modes of life are, as we have seen in Chapter I, reactions or answers-back to the Struggle for Existence. On both lines there may be intensified parental care. Our question now is: What are the particular advantages of the socialised or co-operative mode of life?

(1) It is evident, in the first place, that union is strength, and that combination may be the saving of small and defenceless creatures. An individual ant is negligible, but an army of ants is a terror. There is evidence that the little people are dreaded by some large animals. Sand-martins are relatively defenceless birds, yet they are little molested, because they live together in large numbers. It is a common sight to see small birds combining to mob a hawk, an owl, or a cuckoo. The smaller monkeys cannot make much of a stand individually, but the crowd summoned by cries may begin to pull an eagle to pieces.

(2) In addition to increasing safety there are

many ways in which the social habit adds to efficiency. A burden, such as a juicy spider, which one ant could make nothing of, may be successfully handled by a little troop. A dozen tailor-ants may combine to pull two leaves together; they may form an extraordinary living chain of three or four to bridge a gap, one holding another in its jaws; they may use their larvæ as animated gum-bottles to bind the leaves together with the sticky secretion from the salivary glands. Pelicans may combine in fishing—an almost unique case—wading in a semicircle towards the shore. Wolves may gain in the winter-pack what they could not secure alone.

(3) There is in a society a greatly increased possibility of permanent products which may mean much, for they represent the beginning of the external or social heritage that counts for so much in mankind. It is a step towards the external registration of racial gains. We refer to the ant-hill, the honeycomb, the great edifice of the termites, the beavers' dam, and so forth. When there is a society with members of different ages, it will be easier to have a persistent tradition from generation to generation.

(4) A society makes division of labour possible; the solitary animal must remain all-round in its development and activities. With division of labour there may be greater efficiency and economy of energy. Thus the young worker-bee in the hive performs many indoor duties before it is competent to pass to the frenzied out-door industry of collecting pollen and nectar. Thus the youthful period is utilised. Or at the other end of the life-curve, the division of labour may allow of the utilisation of the aged. Thus in the case of the wild-bee Halictus, the old queen, who has ceased to be a mother, becomes an experienced portress at the door. That there may be a seamy side to the division of labour we have already recognised; the individual may be over-subordinated as in the honey-pot ants.

(5) Although the finer animal societies probably started with well-endowed animals, it can hardly be doubted that the social inter-relations would favour the advance of intelligence and kindly sympathy. How intelligent the social rooks, cranes, and parrots; the beavers, the viscachas, the wolves, the wild horses; what repertories of ready-made efficiencies in the in-

stinctive ants and termites, wasps and bees. It may be thought that this is arguing in a circle. With one breath we say that plastic and sympathetic animals make societies, and then with another we say that societies make animals clever and kindly. But we believe that it is just in such virtuous circles that evolution has worked. Well-endowed animals send out social tendrils, and the incipient society forms a sieve in which variations in the direction of sociality are preserved, while variations in the direction of the anti-social are winnowed out, and cast as rubbish to the void. Evolution has often been like a spiral that bends down on antecedent levels, and then re-ascends to a higher level. When an aggregate becomes an integrate, this reacts on individuals, pulling them up a bit, giving them a vantage-ground for further variations on the same line. To take a definite illustration: clever and kindly animals will tend in certain circumstances to form a society; in a society there is survival value in calls and cries, signals and words; there will be a stimulus towards a vocabulary, even if language in the strict sense is never attained before man; but the acquisition

of audible means of communication will promote more intelligence and good feeling. Those who disavow all suggestion of Lamarckism (the entailment of individually acquired gains) will be content to say that the social framework serves as the sieve which winnows variations and secures the survival of those that are in the direction of increased sociality. Our theory is essentially the same as that expressed in the familiar saying that "Nothing succeeds like success." Evolution works on a compound interest principle.

(6) Social or co-operative life is essentially marked, as we have said, by some measure of self-subordination; and this is one of the roots of morals. There is much of this self-subordination in parental care, especially on the mother's part, and the solitary, self-sufficient animal may have strongly flowing springs of good conduct, but there is something subtler, though not deeper, in corporate life. The social animal has to habituate itself to work in a team; it is one of the greatest of moral lessons to learn to play the game. In animal communities there is a powerful social restraint on individual impulse.

(7) Given a firmly established animal society,

is there not another advantage, that free play is allowed to variations which would be impossible in the conditions of individualistic life? Some of the types in a highly evolved society of ants or of termites are very extraordinary. In some cases there are castes so queer that no one yet knows what they mean. Some of these new departures may be in the vanguard of progress. In any case the social or co-operative *milieu* allows of tentatives which would not be possible on the "each for himself" mode of life, partly because the individualist type must remain all-round, everyone his own everything, and partly because the struggle for existence is so keen that novel idiosyncrasies are apt to be nipped in the bud. The individualistic type is like a man rowing against the stream; the social type is like a steam-yacht that can afford to play tricks. Yet we must not forget that man was an artist while he was still a cave-dweller, living a life that was in its austerity nearer to the animal struggle for existence than to the socialised endeavour after well-being that we are familiar with to-day. But the cave-dweller had probably one thing in his favour as regards art—he had leisure.

TOLL OF SOCIAL LIFE

To animals that have adopted or have been forced into some form of social or co-operative life, there have come great rewards in the course of evolution, but there has been in some cases a price to pay. Similarly, while there is a deep truth in Rousseau's saying: Man did not make Society, Society made man, there are handicaps to progress involved in departure from the "each-for-himself" policy. The robust all-roundness of the solitary creature is lost, and there may be an over-subordination of the individual that leads, like parasitism, to a serious reduction of function and an impoverishment of life. One has only to think of the big-jawed soldiers among the termites; they serve the interests of the society, for they constitute an efficient protective and aggressive caste; but their jaws are quite unsuited for chewing the wood on which termites feed, and they subsist on the surplus that is given to them by the workers. This is, as it were, a telling diagram, and there are many other examples among animals of what we are familiar with amongst ourselves—the over-subordination of the

socialised individual. We are using this not as an argument against the social régime, for that would be absurd with an organism so inherently social as man is; we are merely pointing out a danger that must be guarded against.

And it is not merely that the community necessarily throws its shield over highly specialised types who could not stand alone, there is in civilised society a preservation of undesirable, under-average, unhealthy types. They are even allowed, sometimes unwittingly encouraged, to multiply their kind. The question of their segregation or the like is beyond us here; what we are concerned with is the fact that the mere existence of a society tends to work in this way, tends automatically to shelter variants that would in non-social conditions be eliminated speedily. The remedy is to substitute for the processes of Natural Selection—often crude and cruel—that go on in Wild Nature, some method of rational and social selection which will winnow in the right direction. This is what Herbert Spencer called the dilemma of civilisation, and we cannot too often repeat his sentence: "Any arrangements which, in a considerable degree, prevent superior-

ity from profiting by the rewards of superiority, or shield inferiority from the evil it entails—any arrangements that make it as well to be inferior as to be superior, are arrangements diametrically opposed to the progress of organisation and the reaching of a higher life."

We have recognised in society the enormous advantage of an external heritage, or, as some would call it, a social environment, which is continued from generation to generation. It is incipient in the ant-hill and the termitary, the bee-hive and the beaver-village; in mankind it has come to be of paramount importance—an entailment of gains from age to age. But it cannot be supposed that this is altogether to the good, any more than the germ-plasmic entailment. There is in the social tradition, in the social institutions, laws, conventions, and even organisations, a terrible possibility of continuing what is outworn and inappropriate. By our social heritage we stand, and yet it is apt to involve the persistence of a net—handed on, for instance, from the early industrial and palæotechnic age—a net in which we are entangled and enmeshed, sometimes strangled in our best efforts. This is the

apology for the Revolutionist as long as he is also Evolutionist.

That social organisation is not in itself necessarily a good thing is evident enough when we turn a critical eye on social insects. In a bee-hive, for instance, we see a fine instance of wealth—the honey in the honey-comb; we see a fine instance of health—for, in spite of Isle of Wight disease, foul brood, and the like, probably largely due to human interference, there is astounding vigour and industry. The social organisation of the hive is a marvel that angels might desire to look into. But when we lift the curtain a little we expose arrangements which, from man's point of view, are revolting. There is a specialised caste of reproductive, non-productive queens, slaves of an exaggerated maternity. There is a specialised caste of reproductive, non-productive males or drones, wastefully numerous, mostly quite futile even in their masculinity, massacred when the pinch of autumn's approach begins to be felt. Furthermore, the whole economy of the hive rests on the existence of a vast proletariat of workers, usually non-reproductive. They are arrested females, the victim

of a tyrannous instinct for industry; their brain-cells go steadily out of gear from over-fatigue; they do not live more than a month or six weeks in the summer. The shining hour does not improve the busy bee. Social organisation is not necessarily a good in itself; it is apt to submerge individuality.

We repeat that we are far from arguing against increased socialisation among men; we are merely calling attention to the loud Natural History warning that socialising will not *necessarily* save either the situation or the soul. Man's mind is largely a social product; man's morals are socially engendered; both science and art are in a deep sense social phenomena; but the mutual stimulation among the members of a community has its antithesis in mutual inhibition; the imitation that operates so powerfully in human society is not always evolutionary; the societary shield that sometimes keeps the artist alive may also shelter the knave.

EVOLUTION OF AN ANIMAL SOCIETY

It is hazardous to try to deal briefly with a difficult problem like this, but there is reason to

believe that animal societies, communities, or corporations arose in two ways—on the one hand, from large families, such as the prolific insects tend to produce, and, on the other hand, from crowded associations or aggregates, such as the mites in a cheese, or the rabbits in a warren. The evolution of the bee-hive is indicated in a general way by the large number of transitional stages that connect the half-domesticated *Apis mellifica* with the solitary bees. As we have already mentioned, several grades of corporate life are illustrated by the humble-bees, though in Britain they never form more than summer communities. But the long inclined plane from the solitary to the social bee is very convincing, there are so many levels. The stages suggest an evolutionary advance, though it must be admitted that the actual ancestry of the climax is quite obscure. There is at least one kind of ant where the only sociality is a quaint huddling together in the winter, forming a living ball that serves to economise the animal heat. From such a case we may pass through somewhat loosely organised communities to an intricacy of organisation that astounds us, and from a single large family to a community of

families. Similarly with many of the gregarious mammals, it is possible to find amongst near relatives herds that include many families and little bands that consist of a single family, with children of different ages. Many such facts favour the idea that an animal society may have arisen from a big family or from a combination of families.

The other theory is that integrates may sometimes have arisen from aggregates. Given certain surroundings, hospitable and abounding in food, great crowds of similar forms may find an easy life. In the extraordinary natural reserves afforded by the great craters of the volcanic region of eastern tropical Africa in Tanganyika territory, there is such rich clover pasturage that it is easy for enormous numbers of antelopes and the like to find sustenance. These have, of course, been gregarious for ages, but our point is that similarly generous surroundings must often have occurred in the course of evolution, and that the crowded aggregates thus encouraged would find it of value to act in concert against common enemies, such as the carnivores. In other words,

the variants in the direction of concerted action would survive.

The advantages of social or co-operative life being great, the question arises, why there are not more social animals. Why, for instance, are there only five genera of more or less social bees, as against a multitude of solitaries; why are there only 500 social species of bees out of the total of 10,000? As already indicated, there are certain ways of getting food, *e.g.*, among spiders, which make co-operative combination difficult; there are exacting surroundings, *e.g.*, on the high mountains, where the few communities that occur find it difficult to survive. Unless very long-lived, like elephants, slow-breeding animals are not likely to be social. Moreover, we believe that the social mode of life among animals presupposes, on the whole, certain original qualities, such as a subtle fineness of brain, some degree of imitativeness, some measure of kin-sympathy, some willingness to subordinate self.

The study of animal societary forms is still young, but it cannot fail to be of suggestive value to students of mankind. This value will be in-

creased, not decreased, if man's apartness is appreciated as well as his solidarity. For a human society stands high above the integrates we study among the beasts of the field. Man has language, rising above words; he has reason, or the capacity for conceptual inference, rising above intelligence; he has a more or less clear consciousness of his own history; he has the power, if he would oftener exercise it, of guiding his conduct in reference to ideals; and he has apparently unlimited possibilities of ameliorating his social heritage. Why does he not rise more quickly beyond the adumbrations seen in herd and hive?

Chapter VII

Man and Nature

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Chapter VII

Man and Nature

THE greatest fairy tale of all is the story of mankind. It is darkly cloaked in the mystery of time, but the searchlight of the present has played upon the past and a slender span of science has been thrown across the ages. To survey the panorama of human evolution let us embark upon the flying carpet woven by the wizardry of science.

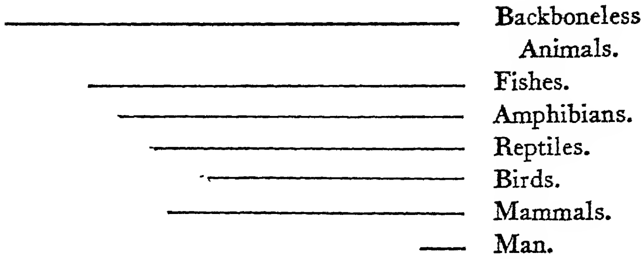
TIME AND SPACE

Once upon a time, long, long ago, eight hundred million years, they say, in the terrible immensity we call space, there appeared the tiny body known as the earth; and here upon this little speck dwells man, in his caves or temples, tents of grass or homes of granite, and here he scuttles from pillar to post for his daily bread and butter,

in the jungle's thicket, amid the poison fangs and sentinel eyes of the serpent, in the land of ice with its midnight sun and trembling Northern streamers, in the brilliant luxuriance of Southern isles with paddle and canoe and plaintive ukulele playing amid the palms, in the great metropolis with tubes and telegraphs, factories and banks, shops and shipping; and here upon this little speck in the vastness of space he comes at last to rest in a lowly pit or a lofty pyramid. The truth from *Gulliver's Travels*, that nothing is great or little otherwise than by comparison, is a fine conception of the stage upon which the drama of human life plays its continuous performance, and true perspective is gained by assailing the engrossing questions—What of the earliest actors and their ways, the first scene and the setting?

THE STAGE BEFORE MAN'S ENTRY

Before the beginning of man's kingdom, turmoil and change for years by the million seethed in the tides of life, as shown by these lines of time duration for the various animal empires:



Many were the great tragedies enacted upon the world-wide stage. Mighty forests were mummified to form the coal of modern industry, and long before the age of mammals and birds was to culminate in the kingdom of man there was the tragic disappearance of the greatest emperors the world has ever known, monarchs for millions of years, colossal reptiles that might have toyed with an elephant as a cat with a mouse, lumbering their slow length along the swamps and marshes of great rivers, nibbling little coniferous shrubs in the mild days of many million years ago. Why they left off living when not one enemy could literally stand up to them is still a baffling question.

MAN'S COMMON ANCESTOR

So much for the prelude to the mammalian symphony where man is the dominant theme, but with the last of the reptiles the stage is reset, and the curtain rises upon the recent, or so-called Cainozoic period of life, where the scenery shows palms and hollies, beech, birch, and ivy, flowers of the earth in bloom, droning bees hurrying through the air, and ancient five-toed horses browsing and gambolling on the grassy sunlit plains. Here upon the edge of the forest lived something more or less like an ape, and more or less like a man. Of one thing we are certain, he was a truly great ancestor, inasmuch as he carried in mysterious creative latency the possibility of our distant cousins the apes, the tentative attempts to go one better in primitive and prehistoric man, and the great diversity of types representing peoples of all nations to-day. Probably he walked erect, at times, and grasped a club or stone in the strong hands, already trained to triple co-ordination with mind and eye by acrobatic antics amid the swinging trapeze and slack-rope trellis of the forest.

It is not at all the suggestion of science that you should look an ape in the face and then hail him as a long-lost brother, even although you may be uneasy about his resemblance to some of your friends, and think him uncommonly like some children—other people's children—you have seen. But the fossil records show that his lineage has lasted at least as long as yours; embryology shows that at certain periods the beauty of his baby is indistinguishable from that of your very own baby; and physiology tells us that the most delicately sensitive chemical and disease reactions are the same for his blood and yours, though they are different for his blood and that of monkeys.

FEET LIKE HANDS

It is true that in your own home, beside the apples of your eye, the thought of the hairy hand and padded palm of the ape is unwelcome, while the memory of the manipulative function of the ape's oddish foot produces a creepy feeling. But let us dissect our own feet. In spite of half a million years' walking by peoples of the past, every

baby has to learn the art anew, partly, we dare to say, because its feet are hands. The prevalent idea that the foot is highly specialised for walking erectly is far from expressing the whole truth. The dissection of the foot is as intricate and puzzling a task as the dissection of the hand; the structures and principles of both are the same, but the foot is restricted to one particular use and the hip, knee, and ankle joints, with their restricted movements, subserve this function, whereas the shoulder, elbow, and wrist joints, with their universal movements, have literally played into our hands. Gripping with the toes is seen in the infant and the adult, and encouraged by the Japanese acrobat with his fingered stockings and shoes, and trained by the man bereft of hands, writing for his living, in the big circus side show with a pen between his toes. So near to the primitive state are the structures of the foot, that we venture to assert that the experiment of selecting and training children exhibiting exceptional mobility of the toes would rapidly result in types capable of surpassing the pedal powers of an ape.

MORE MISSING LINKS UNNECESSARY

To return to our ancient ancestor, we find that students of man, anthropologists, are still searching strenuously to demonstrate a perfect series of links carrying us back to a common stock which also gave rise to the apes; but links so good have already been prised from the rocky moulds of time, welding a chain leading to association with a common ancestor, that the difficulty would be to adduce evidence for *dissociation.* But while the record of the rocks cannot be gainsaid it is open to various interpretations, and we turn with satisfaction from tombs to cradles, from palæontology to embryology. It is well known that the various changes which an animal undergoes in its prenatal development are, as it were, a telltale story of a passage through many primitive types. For example, we ourselves made and cast aside or bettered such structures as the gills, heart, and kidneys of a fish and the brain and tail of a tadpole in the factory of human form. Bearing in mind these two sets of evidences, we cannot wonder that anthropologists have at times expected to trace modern man away back through a series of prehistoric men to an ancient ancestor.

BIOLOGICAL PITFALLS

But this expectation has been in some measure disappointed, and we must recognise that difficulties exist. Though anthropologists are few, though the earth has not been systematically searched, though the silent sea floor may never yield its historical treasures, though our knowledge of the types and culture of the prehistoric past depends upon a few specimens—the fragment of a skull or an implement of flint—yet, already certain extinct specimens of man, better in type than our so-called modern selves, are ascribed a greater age than more primitive types also extinct. This is a difficulty. Then, again, the figures in the prehistoric ledger do not quite balance with expectations suggested by the theory that embryonic development recapitulates racial evolution. Skilled students of development find the steps of animal growth not quite the same as corresponding stages in more primitive types; steps are often missed altogether; and the order of other steps may be reversed.

MODERN MAN AS ANCIENT AS PREHISTORIC MAN

However these things may be, we need not refrain from the bold suggestion that modern man may be traced back not necessarily through, but on a line collateral to that of all primitive types, as far as the common ancestor, who was really the anthropological Pandora box that gave rise within a short time to the apes and their relatives, prehistoric men and the races of to-day. Briefly, man and apes, living and extinct, diverged from a common ancestor at the same time, as far as time goes, in a period guessed at several million years. Moreover, the ways of life, folk-lore, implements, crafts, customs, and organisations of primitive tribes imply a source of higher culture influencing their societies. Anthropologists regard certain types of prehistoric men as offshoots from the common stem, rather than as on the direct line of our ancestry, and suggest that the modern man type is much older than has been hitherto suspected.

MAN HALF A MILLION YEARS AGO

This much is certain, that 600,000 years ago man lived a lonely existence probably in widely scattered bands, but his life flickered out in darkness, no written record of experience illumined the outlook of his children, and it was only within the little span of the last six or seven thousand years that written speech so swiftly sublimed man's mode of life from Nature's, so boldly set the sails of civilisation, spliced the mainstay of society and held the helm of science and industry upon the high seas of accumulated experience. Every day we become much more truly children of the past, but our ancestors were individuals of isolation.

FROM PITHECANTHROPUS TO TUTANKHAMEN

It must be clearly understood that people like ourselves and Tutankhamen belong to the 6000-year short period, while the people we are now to discuss in brief and popular terms belong to the long cycle of 600,000 years.

About the beginning of this time there walked

in the island of Java a man of average height with a brain of 900 cubic centimetres in volume, that is to say, intermediate between an ape's 550 c.c. and our own 1450 c.c. The pattern of his brain seen upon the discovered piece of skull shows that he was left-handed. Probably he used clubs and stones in the chase of small animals and was afraid of the mammoth and rhinoceros in the days before the Ice Ages fell upon Europe. Who knows—he may have idly experimented with the sap of the rubber trees. Certainly he never dreamt of causing the great modern scientific controversy resulting in five votes for his being an ape and seven for his being a man.

Science was next concerned with a jaw found at Heidelberg, a massive machine with large special grinding teeth that crunched roots and fruits and small animals 400,000 years ago.

THE PEOPLE WHO PLAYED AT PILTDOWN

Knocking at our own door came the Piltdown man from Sussex, high of forehead but broad of nose with a goodly-sized brain of 1350 c.c., the

equal in size of many a lower type to-day, when the Bushman's is 1350 c.c. and the Veddah's of Ceylon 1250 c.c. Here we have a user of flints in the fluctuating climate of the Ice Ages, a possessor of the civilisation of the period of 200,000 years ago, a fine old English gentleman, or, as Keith maintains, a gentlewoman who took the air upon an afternoon by the river's bank to see the mammoths spraying in the water or the hippopotamus wallowing in the marshes; and sometimes she crouched in terror when the woolly rhinoceros arose amid the herbage like a monster of evil. Was she obedient to the behests of her lord and master? Had she one? Did another achieve her by right of purchase, say a few pretty shells from foreign parts? Was she subdued when the great Neanderthal race arrived in England?

RHODESIAN MAN

Darkest Africa, with many strong claims to be the cradle of mankind, produced one of her great secrets at Broken Hill, namely Rhodesian man, who roamed the sources of the Congo and Zambesi when our Piltdown people played in

England. His brain occupied 1300 cubic centimetres; his skull thickness was 20 per cent. of the length of his head, like a gorilla's, which is 26 per cent. compared with ours at 8 per cent.; his general cast was brutal, gorilline, massive. All his features stamp him a "cart-horse" type; but, poor soul, his teeth tell of toothache in days when, surely, dentifrice should have been unnecessary.

LIFE IN NEANDERTHAL TIMES

At Neanderthal there were found some very striking remains of an ancient race, which is known to have been distributed in a wide belt from Piccadilly to Palestine, through Germany, Belgium, France, Spain, Gibraltar, and Malta. It is probable that the sea trapped the Neanderthalers by the hundred when the Atlantic broke the western barrier of the ancient fertile Mediterranean valley. While the Neanderthaler shows the heavy eyebrow ridges of the ape, we cannot but admire his skull capacity of 1600 c.c., well beyond our own, though the higher intellectual centres of his brain are held to have been less developed than ours, and the brain is the place more

than any other where quality counts. Generally speaking, the larger the man the larger the brain, and, as the Neanderthaler but reached the moderate stature of five feet, we must surmise his possession of strongly developed centres of, say, olfactory function. However, he was an artisan in the manufacture of flints, and he had learned the use of fire, the flames of which were destined to lick the wealth of Nature to the life of industry. Were they happy care-free bands that gathered round the warmth and the glare while flint scrapers rasped in dressing beaver skins? Did the ghostly glowing embers warn the chief of short shrift in his old age at the hands of younger braves? Did the gleams betray anxiety on heavy visages, lean as the trails of barren lands, puzzled to see the hippopotamus seeking the sunny South and an age of ice descending, desperate to contend with lions and bears for the shelter of caves in times when a wintry blast scorned the best-laid plans and united efforts of many days' pit-digging for mammoth trapping? Big-game hunts were organised affairs; the individual hunted smaller game and gathered roots, and fruits, not

to speak of frogs and caterpillars, still sold in France and China. Interesting surmises may be made regarding Neanderthal times. Stone weapons won by laborious toil but buried with the dead are evidence of intense and reverential concern for future life, and postulate thus early the possession of the reflective mood, characteristic of man of all times and places, be he sage, savage, cannibal, or Christian. Already we see the hero-worship of Nature's pack leader in submission to the dominance of the chief. Nature's indifference to age in man's ingratitude to man, customs flourishing in barbaric splendour at the moment when the Eskimo has been known to help at the hanging of his aged useless father, though devotion has also caused him to soothe his grief in suicide at the death of his mother. But death to the non-productive in the pinch of Arctic wastes is a tenet of the tribe, further elaborated by destroying female children unless they have been sought in marriage before birth by the prospective husband or his father. Who shall judge if the stinging lash of tribal law fell more bitterly upon primitive man than it falls upon the leader of

to-day, despised for defeat in the great game of life?

The Neanderthaler's mode of life was successful in that it served him for upwards of 200,000 years, but, alas, down he went like ninepins before the first race of true men, just as we see to-day how the ripples of civilisation in the placid lagoons of Southern Seas may spread a virulence due to change of habit, as the alert virility necessitated by cannibalistic warfare is replaced by the degeneracy of lethargy, or due to the introduction of diseases against which the natives have no racial immunity, or to the use of shot and shell when primitive views do not fully accord with civilised ideas in the sale of silks and spices.

THE FIRST TRUE MEN

At Cro-Magnon in France were discovered the remains of these first true men, six feet to the Neanderthal five, a beautiful head with a brain of 1730 c.c., that is, almost 300 c.c. larger than ours, teeth like those of to-day, and no massive jaw, no beetling simian eyebrows. He lived in Wales, France, and Spain, and was probably akin

to the extinct big-brained Boskop race of South Africa. Cro-Magnon man was the last of the Old Stone Age or Paleolithic men, a great hunter, an artist in colours, an engraver and a sculptor. There were herds of mammoth, reindeer, bison, and little bearded ponies on the plains, and he painted scenes of the chase in red, yellow, black, white, and brown on dark cavern walls by the light of torches or lamps. Although the Sikhs of the Punjaub to-day are very like Cro-Magnon man in stature it is believed that this ancient race became extinct, probably because the herds were dwindling and he had not appreciated the art of agriculture which began with the New Stone Age man, Neolithic man, with his bows and arrows, polished stone axes, needles finer than the Romans used, pottery, cooking, weaving, and domestication of animals.

THE GOLDEN LESSON OF THE NEW STONE AGE

Let us note the important fact—Neolithic man had evolved another way of living; while, like his predecessors, he was still dependent on the plants and animals of the earth, he had mastered

the golden lesson not to kill the goose. Neolithic life, which began some 15,000 years ago, brings us to the modern times we spoke of in the 6000-year period, and already the world is peopled with races blonde and black, with customs different as day to night. Such a peep into the principles of past life enables us to sense a trend of human evolution, but advises the exercise of caution and reserve in the forecast of the future and the controversial study of man, social, parasitic, commensal, and individual.

SOCIETY MADE MAN

Ancient man probably led an isolated existence (just as higher apes are few and far between today), but by lending a hand for the common good, by taking station like the wolf in the hunting pack, by taking turn at sentry-go like horses, deer, and buffaloes, his kind grew and multiplied. There never was such a thing as a self-made man. Man was made by society, which gave rise to the necessity for speech and written language. Man, by himself, is a poor dispirited Ben Gunn upon Treasure Island; he needs the flint of other men's

minds to strike the spark from the steel of his imagination. It is true that some of the animals have social organisations, as depicted in Chapter VI, but man and his societies have been peculiarly subject to what we would describe as continual reciprocating acceleration. We have noted the dominance of big-brained types. Rugged features, massive jaws and teeth have yielded to the magic of the mind, and popular writers imagine a future faceless, toothless race, well-nigh trunkless and limbless, in fact, all brain and eyes together, living in machines performing the wishes of the master mechanic at the touch of a button. How vainly science tells a pretty girl that her face is a mere scaffolding for her teeth, merely an anachronism, when she is so imbued with the classic cult of the beautiful that her studied smile reveals her teeth on all occasions.

> "Her lips are like twin-budded roses,
>   Whom ranks of lilies neighbour nigh,
> Between which bounds she balm encloses,
>   Apt to entice a deity."

As long as beauty is seen in such things it is certain that man will use scientific organisation to

preserve structures liable to disappearance through disuse or disease. While modern business provides soft and concentrated foods and pays a man to sit all day working with his mind while his teeth drop out, his sinews soften, and his intestines stagnate with poison, medical organisations indicate suitable food, detect disease, prescribe prevention, instruction, and exercise. Herein lies a network of reciprocating acceleration between man and society, but let us take a more intricate instance of co-operative interaction, as elaborated and intensified by war. Shot and shell wounded faces beyond recognition, but the patient's relatives were consulted, his photographs examined, the artist painted him anew on canvas, the sculptor modelled him anew in clay, the anæsthetist prevented pain, Pasteur and Lister prevented infection, and the surgeon made him a new nose or mouth or chin or face. Society has not yet fully accelerated to the pressure of medical science. While we see the dwarfed, deformed, and idiot cretin transformed by a grain of the missing thyroid elixir to the beauty of human form, and the infant of a week old acquiring immunity against the microbes of the earth,

man has not yet co-operated to stamp out the field-marshal of the hosts of disease, the great curse of civilisation called syphilis; yet it can hardly be doubted that the future cavalier waiting upon his fair lady's sire with a ring in his pocket will carry in his hand his full medical report, blood and brain attested.

THE SCIENCE OF BREEDING WELL

The science of eugenics or good breeding has surely come to stay. It is the greatest discovery ever made, well-nigh placing man in control of his own destiny, an immeasurable leap from the lap of Nature. The stock-farmer stakes everything upon it; and the State may ultimately completely regulate marriage as it at present determines such social customs as law and education. The subsidiary and associated subject of birth control has been described by an eminently original officer of public health as the greatest event of biological history.

But let us ponder for a little over some of the difficulties of the problem of eugenics. The super-normal man, the genius, may live unrecog-

nised and die misunderstood. Wagner might have perished in poverty but for keen appreciation on the part of the ill-balanced mind of King Ludwig II of Bavaria. Micawber, it is said, was the father of Dickens. In what measure shall the disparity of type be adjusted? How shall latent change and culture be safe-guarded? A tolerant golden mean may solve the problem. A well-known text-book suggests that the adoption of art as a livelihood is a symptom of a bias towards insanity. Must that still be true when advertisement posters and boxes from the pastry-cook's are the work of masters in colour? Some of Epstein's work pleases the uninitiated eye at once, but his Venus has no face. He must be portraying something different from what we mean by the term. Had the word not been used in a relation so provoking to accepted usage, we might have imagined a representation of the mother of evolution with a harking back to quaint figures and charms of primitive tribes, and a forecasting of vigorous simplicity to come.

SIZE OF BRAIN

Will man acquire a greater brain in the future? Brains of the past have been larger, and the great majority of men, in spite of cheap printing, are provided by modern conditions with such a monotonous routine of life that there is little exercise to develop the flights of imagination, expression, and invention found in the culture of the past and the medical, mechanical, and chemical arts of the present. As these achievements have been made by the present standard of brain, even the boom of culture by broadcasting may not encourage an advance in size. The Greeks were so keenly alive to the culture of the mind that they forgot their hands and well-nigh became parasites, called free men, upon a nation of slaves who did not vote, but probably lived happily and more comfortably than their aristocratic lords whose manual and business affairs they conducted. The Greek would certainly have objected to an eight-hour working day, and his homes, dress, and diet were characterised by extreme labour-saving simplicity, so as to facilitate the devotion of his day to high thinking and speaking. The Greeks had

not sufficient organisation between the artist in thought and the artisan in industry, else their somewhat parasitic economy might not have toppled down. Apart from increase in quantity there may be a refining of brain quality, but this may be difficult to distinguish from progress due to improved educational methods. However, the moment the lives of men are influenced by discoveries of science for good or evil, the plastic brain evolves reciprocation to a correlated level. The Jew is credited with the most highly evolved brain because subjection to vicissitude ground his wits to a keener edge while his enemies lay in the rut of protection. Sir Frederick Mott says that the Jew has paid the price in greater incidence of mind disorder, and while one might argue that the levels he possesses in common with ourselves ought to be all the more stable, it may be that development of brain involves greater delicacy of elemental interaction. This much is apparent, that modern ways of life with all the handmaidens of civilisation, the greatest treasure of which is the written record of the past, endeavour to cast the light of experience upon the future; and according as the solutions of problems are true or false

so shall the accumulated effects tell upon future ways, and influence the pendulum of that most intricate of clocks, of cogs and wheels and hidden springs, of levers, balances, and jewelled movements meshed in the mind of social man.

WAR

The primitive past still rubs roughly through civilisation's veneer; war is more than ever savage, though Tennyson predicted

> "When the war drums throb no longer and the battle
> flag is furled,
> In the parliament of man, the federation of the world."

In spite of common ancestry we have diverged enough to lead a cat-and-dog life with our relatives black and white, red and yellow.

> "East is East, and West is West,
> And never the twain shall meet."

While some argue that mountain, sea, and desert barriers have resulted in the isolation of races and the encouragement of war, we know, on the other

hand, of bitter feuds of many years' duration among tribes of the same race such as the famous Crows and Dakotas.

TOLERANCE

A huge racial intermingling experiment is now in progress in America, and transit will soon be so rapid throughout the world that with due respect to Kipling the twain shall blend in one, though many will disappear in the fusion. All living things tend to differentiate, therefore we must not dogmatise beyond forecasting a uniformity of mental outlook in tolerating the views of each other. This has already begun. There is a fascination in the large city's spectroscopic blending of peoples. In London the negro looks upon men white and smooth of skin, while his ancestors were scarred and mutilated with the decorations we display in dress and the customs we celebrate by a wedding or the donning of long trousers and a bowler hat. In Constantinople cafés diverse origins mingle and dance to an orchestra of obscure nationality, while the ancient edifice of Christendom, St. Sophia, still stands

monument to the bitterness of faith against faiths these 1300 years, in an age when man begins to control his tribal instincts of aggression.

RELIGION

Had this toleration been possible in the past, then Egyptian civilisation might not have sunk into the mysterious silence of the desert, for King Akhenaten—father-in-law of Tutankhamen—founded a new religion, a remarkable feat for a youth just out of his teens, considering that most of us inherit the religions of our parents as a matter of course. Indeed most social organisations are unconsciously adopted—whether political, educational, occupational, or trade unions. Akhenaten's natural religion perished with his death as a young man of twenty-eight years, but his race paid the penalty for its inability to place the young head upon its old shoulders.

Man has always been concerned about his future, an anxiety giving rise to particular customs, secret societies, and modes of life, with diverse results in different places. The pyramids and tombs of Egypt are an instance of the obsession

of the mind by the future of man to such an extent that his tomb was commenced during life with the co-operation of architects, artists, sculptors, and complete house furnishers to secure the greatest comfort and diversion for the future of the lord and master who would often spend a pleasant day's picnic in the desert to inspect the work and picture to himself what a fine time he was going to have when he died.

The belief in supernatural powers has given origin to the practice of tapu or taboo among South Sea Islanders, where a man may preserve his possessions from communistic appropriation by placing such a spell upon them as to punish the transgressor. Robert Louis Stevenson remarks on the tenacity of the custom and belief, for tapu may be declared in secret, or by obvious public sign; and, in spite of European supervision, the ancient cannibal chief is still called upon to exercise a tapu for the benefit of the island crops and fishing, a practice not injurious or whimsical, but akin to our close season.

COMMUNAL CUSTOMS

Communism by the custom called *kerekere* reached such a pitch of perfection in Fiji that it proved an effectual bar to European methods of trade, for the goods belonged to everyone and anyone, while in Savage Island, Polynesia, the natives laugh heartily at the ridiculous European idea that a man who earned a sovereign should keep it for himself; such absurd individualism is quite unheard of and would never enter their imaginations. Peculiarities of possession are shown in Eddystone Island, Melanesia, where a man may plant and own trees upon the land of another, the precedent being set by inheritance laws bequeathing a man's land to the sister's children but the trees to his own, a custom, according to Rivers, brought about by strangers, accustomed to patrilineal descent, transmitting trees to their own children, while the matrilineal organisation of the invaded island governed inheritance of the land. Such a reason may also explain the Melanesian speaking of *our land*, *our club*, the common ownership of indigenous inhabitants, but *my bow*, *my arrow*, introduced implements of

private possession. Again, *our canoe* may not refer to its construction by united effort because he talks of *my house* though many helped to build the home. Communal ownership is to a certain extent bound by relationship in the joint family systems throughout India and Melanesia.

Age-grades of boys born within a period of, say, ten years form communities sharing the prosperity of each individual in Polynesia, West Africa, and New Guinea, where eating a chicken not cooked at the age-grade fire would be a punishable offence in these lands with flats for bachelors. "Commensal" life is beautifully illustrated in Papua, where a house may hold a thousand people, cannibals steeped in the intricacy of tribal laws necessary for the preservation of their social organisation, delighting in their ghostly rows of grinning skulls, thrilling memories of silent paddles dipped from sinister canoes, swinging clubs, savage cries and feasting. In the villages of the Sea Dyaks of Borneo the common house lodges upwards of fifty families, the verandah is the main street adorned with human skulls, trophies of these inveterate head-hunters after the manner of horns and skins in the halls of the big-game

hunter at home. But the heads or rather the victims will serve the victors as slaves in the future world. No wonder it is a duty to a kinsman that his departing spirit should not travel unattended, no wonder head-hunting should be as necessary as providing a wreath or a tombstone. In other corners of the earth heads of ancestors are preserved with the piety of Isabella and her pot of basil. Here we are very close to the practice of cannibalism, which is sometimes due to the belief that the inexplicable condition of death was to be countered by eating the body to secure the reincarnation of the spirit of the departed in one of the tribe. On the other hand, at one time, in Southern Seas cannibalism was probably initiated by over-population and scarcity of food, for laws existed debarring the possession of more than a certain number of female children under the penalty of fines, which were frequently paid.

MARRIAGE CUSTOMS

Such practices are responsible for polyandry, still observed in the Marquesans. The islands of Polynesia and Melanesia—lands of bodies

saffron bronzed, rainbow-enchanted flowers and ferns, and gorgeous coral girdles in a sea of surf and sun—also illustrate the opposite practice, polygamy, where a man has as many wives as he can afford at the cost of a few pigs apiece. But polygamy is not always confined to the rich; it used to be necessary to secure ten heads before taking another wife. It may be a privilege of age, as in Pentecost Island, where society demands that a man marries his grand-daughter. Old men also monopolise young women in Australia, so that the modern association of sixty and seventeen is no new story of power and position.

Marriage customs profoundly influence life in West Africa, where a man may refer to a whole group of men as fathers-in-law though some are childless, and he has to buy his own children from them if he wishes them to inherit his goods; and, of course, he may have a hundred mothers-in-law, all forbidden to speak to him, while in the South Seas the mother-in-law must pretend to be angry with her son-in-law, probably an origin of the odd way in which she is made the subject of jocular remark among ourselves to-day.

THE OLD AND THE NEW

Though modern civilisation is doubtless marked by strongly individualistic lives, and suggests the slogan "each man for himself," we still band together for protection against the parasites of piracy whether they ply upon the high seas, the business markets, or the seamy side of life; and war may swiftly precipitate the intricacy of our organisation to the simplicity of the savages' commensal meal. Not so long ago the abolition of slavery began, though the solicitude which, according to the writings in the tombs of ancient Egypt, the nobility bestowed upon their slaves, is ample evidence that the custom thus early provoked misgiving in a conscience concerned with the future. We may feel superior to primitive man, but his life may present more intricate problems than ours. In the aboriginal of Australia our fossil relatives of the Stone Age are still alive. He may have to marry his mother's mother's brother's daughter's daughter; his father may have settled upon the mother of his son's wife before the latter was born; from boyhood his status is advanced by initiation through rite after

rite, by torture after torture, till adult life finds him tyrant and parasite upon his wives and the younger men, with all that is best taboo for them but not for him.

WOMAN'S PLACE

Throughout primitive society woman occupies an inferior position, yet she is chief of the council chamber among the Hurons and Iroquois—a rôle that she has sustained among diverse races old and new. The fighting chief is typically a man, yet woman's right breast was lopped off among the Amazons to facilitate the drawing of the bow. We have even read of an "advanced" African tribe where the woman can get immediate divorce if her husband has not sewed her petticoat properly. But the age of the emancipation of woman is distinctly modern, and its future is beyond prophecy.

SEX AND HORMONES

Nature has endowed the animal frame with secret cells whose locks are combination cyphers

still unpicked. One in the brain, the pituitary, may by excess make a giant; one in the neck, the thyroid, may by deficiency produce a dwarf. Another pours out the passion of anger and prepares for a fight; others are isolated islands to produce insulin; and others are concerned to make a man of a boy and a woman of a girl. There is a border-line between sex which sometimes needs the microscope for the differentiation of type. The nearer the border-line the greater is the resemblance in appearance, action, and mentality; the further away from the border-line, the more male or the more female are the details of form and function.

A striking instance of the border-line type is furnished by the "free-martin," that is to say, a heifer co-twin with a bull, which develops the appearance and mentality of the latter. The animals are connected during development by common blood vessels, and one physiological interpretation of the strange phenomenon is that the more strongly developing male changed the structure of the co-twin female by chemical secretions poured through the common blood supply. Yet in the goat, where free-martins also occur, there

is a separate blood supply for the twins. The male mask of the free-martin is said by Lillie to be further indicated by the fact that the heifer does not breed, but Low has shown that this is not always true.

Enough has been said to show that typically differentiated sexes are found well to each side of the border-line, and that the advance of the one is not necessarily to be sought in imitation of the other. Woman has fresh fields to conquer, a line of evolution all her own. She is not so specialised as man, that is, so far removed from primitive or child-like type, and is therefore fraught with great possibilities for the future. The child type and the female type are both more refined than the adult male. The female gorilla's skull would have been considered as belonging to a different species from the male's had they been found as extinct specimens. Again, the skull of the young orang is almost like a child's, and, so, different from the adult orang's.

Everyone recognises the evolutionary ambitions and finenesses of youth, in comparison with which it always seems that the ideals of their elders have been worn thin by the friction of

life. The little heads beneath the paper helmets of the nursery battle-field, the little hands plying their balls and skipping-ropes so skilfully, the little lips kissing their dolls so sweetly, have a much finer and more honourable sense of the by-laws in the great game of life! Late one evening we remember seeing a *première danseuse de ballet* aged six, with born command of the pirouette and ripple of floating limbs, and an able corps of tender years and swirling skirts, perform before an admiring audience of six mites seated on the kerb in the slums beside a police station, where in riper years, their youthful principles worn thin, other actors have played in other scenes. It is but just to remember Mercier's confession that "we are all criminals but for the absence of sufficient temptation."

NOMADIC LIFE

In conclusion, let us allude to the romantic and primitive modes of life seen among the nomads. The Bedouin disappears in the sand cloud of the desert: the Eskimo leaves his ice igloo with the spring, and the family oomiak bears away the

tribe to new waters where the hunter's kayak skims ice-covered patches to seek the timid seal: the tall Patagonians of the pampas pursue the little camels of the Andes, the lamas, on trails thousands of miles long—the animals are killed heavy with young, as the latter possess the desired commercial quality of skin, and vultures and coyotes pick the bones; but the European spirit-dealer picks the pockets and degrades the minds of the Patagonians till the race is at the end of its tether: over the plains of Labrador, southward in the silence of the snows, treks the vast herd of caribou, timidity and shyness personified; but with the delirious fever of migration upon them, bold as brass they march with clicking hooves through mushroom cities sprung upon their ancient trails, and vanish in the storm, shaggy, gaunt, bearded, and icicled, while the nomadic Indians hang upon their flanks, North in summer, South in autumn, year in and year out, as of old.

Man began life as a nomad, a wanderer from place to place, and still the romance of the road is strong within him. The desire to seek something new prompted him to rise upon his feet to see better, automatically made his hands and cul-

tivated his brains, which taught his primitive societies to move ever onward for sustenance. Then he harnessed Nature to his aid by agriculture, and at length was able to support six million folks in London where a hundred once meant famine. Now his brain and hands dominate as never before. The latter have survived in a generalised and ancient state, for five digits were common to each foot of the ancient horse, though each foot has but one digit to-day, when the elephant has five, the hippopotamus four, the rhinoceros three, and the camel two. The good old days deserve their title for our inheritance of hands alone, but our brains and books reach forward to the new; they are still nomadic. The buffalo hunt is nothing to the slaughter of a bacillus, nothing to radio-graphic seeing, wireless hearing, aeroplaning and submarining. The nomadic instinct of man has allowed him to glory in his generalised state of evolution, while his mighty mechanics and minute devices are the specialisations which the rest of Nature has sought in sacrifice bound upon the rim of Nature's wheel, while man, unfettered, rides upon the hub.

A question mark flies as pennant upon the ship

of civilisation, riding out the stress of storm, until, becalmed in the port of retrospect, refitting may be planned. But the Blue Peter flutters at the fore, the big screws are churning, the fenders come aboard, the siren hoots, the gong goes, and she's gone—with human freightage on the tides and times of life.

Envoy

By Prof. Patrick Geddes

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HERE a number of independent students and investigators amid the world-infinitudes of life, still so little charted, have set themselves to co-operate, as such specialists are yet too rarely beginning to do: so the writing of a "synthetic envoy," such as they invite, is indeed, as they have foreseen, a difficult task. Yet their brief preface clearly indicates the underlying unity of plan for their varied discourses, and it also tells us the source of the demand whence come their endeavours to supply. And all three are encouraging. It is well that the latest and largest of University Extension audiences, the Workers' Educational Association, should thus show response to Solomonic wisdom, in seeking to compare the ways of life in nature with those of man; and also that the University which has longest and most fully been maintaining a high standard throughout the education of its region

should here yield such individual expositions, yet co-operative team-work, as are needed to answer so vast a question. They have thus agreed upon a general plan for their series: that of outlining the chief ways of life as three—the individualist or independent, the parasitic, and the co-operative or social.

To bring out as clearly as may be this unity of plan, underlying the rich variety of the ways of animal and plant life by turns, let us rapidly glance anew over the preceding chapters, and with special interest in their initial question, of what suggestions nature's life may offer to understanding man's. Appropriately to our industrial age, with its economic individualistic theory, and its political thought in harmony with this—ideas with which Aberdeen is so commonly credited, and we believe even more than it deserves—Prof. Thomson wisely begins with stating the case for individualism; and this to its high perfection, as in his admirable survey of the life ways of the badger, for whom the reader's esteem cannot but be increased. Yet this legitimate defence of individualist vigour and its values is far from that of Strindberg and other extreme individualists;

since it carefully corrects the cruder statements of the struggle for existence by recalling Darwin's own presentment at its best: with appreciation therefore of the co-operative and communal ways of life as well as of individual ones. From his comparison of both these ways of living, there emerges a broad outline of their respective excellencies, yet limitations, their advantages and disadvantages. Thus lightly and gently, yet definitely, he exposes the weakness of the old individualist and old socialistic theories, hitherto so sharply opposed, throughout recent times increasingly. His sagacious hint thus naturally follows, of needed synthesis of the values of both views and methods, though this is left to the reader further to reflect upon and inquire into.

After this essential introduction, come more special chapters, each of clear and simple popularisation of ways of plant and animal life, independent or associated. Dr. Skene necessarily begins with that brief outline of essential plant physiology which is still practically unknown to most otherwise educated people, yet upon which the whole organic and human universe depends for its maintenance: and his exposition is brought

up to the socially suggestive conclusion, that though the green plant is the most independent of living things, its life is yet not capable of being so individualistic as that of many animals; but has inter-relations of the utmost intricacy as well as comprehensiveness, as are being gradually unravelled.

In his next chapter the third way of life, that of parasitism, is broadly outlined; starting with the interesting story of the mistletoe, and going on, through the complete parasitism of the dodder, to that of the innumerable fungus-pests, to combat which is of such importance to agriculture. Thus the reader is prepared to enter upon some understanding of the varied underworld of bacteria; in many ways so dangerous to life, yet in larger ways so fundamentally necessary; as above all to the making of the soil itself, yet even to many seeming-individual organisms as well. An important feature of this chapter is its discussion of the probable origin of parasitism, as illustrated by a gradation of examples, of which a good many can be verified by the field-naturalists and nature students. Here is a good illustration of evolutionary thought, that of interpreting

apparently distinct living forms as not fixed in their ways, but representing this or that stage of an intelligible series of phases, through which some go farther than do others.

Next comes the needed similar outline of animal parasitism, again illustrated by examples from many forms and levels of life, ranging from the sea-shore and the fish-market to the miseries and horrors of many human diseases. We cannot but regret that between modesty and lack of space Dr. Rennie has not given us an account of his own brilliant achievement of elucidating the disease which has so lately ravaged our bee-hives; yet it is well to have concentrated on main outlines of such human parasites as those of hookworm disease, malaria, etc., since their comprehension is increasingly leading towards ameliorations of human life surpassing all previous advances of sanitation, and thus preparing a safer and better future for vast regions of the world, both Old and New. In no practical field of human life can better illustrations be found of the value of learning nature's ways towards guarding and amending those of man.

After these contacts with diseases, comes ap-

propriately Dr. Stuart Watt, to lead us out into the fields and to the forest; pointing out, as he goes along, the local, yet practically world-wide, communities and partnerships among plants. Nowhere better than in Aberdeenshire can people be familiar with their characteristic upland landscapes, there so often of dark pine forests among vast expanses of purple heathery hills: yet nearly everyone still thinks he understands the life of pine or heath, as each growing naturally on its own roots, and scarcely one in thousands yet realises how these roots depend so essentially for their efficiency upon their deep-lying fungus-partnership that keener observation reveals. For the pine-rootlet is closely mantled by an interwoven web of fungus-threads; and this root and mould system (mycorhiza) is no mere case of parasitism; but a reciprocal association, a truly co-operative partnership, a veritable symbiosis, recalling that of alga and fungus into the lichen. Yet even botanists have only of late years realised that the glorious exuberance and vast extension of our common heather over its moors and hills are yet more deeply dependent upon its association with a kindred fungus-mould, in ways the most inti-

mate and thoroughgoing. For this mould not only weaves around the roots, but extends throughout the branches; it penetrates the leaves, and even into the flower, and to its ovary and seed, so that the young seedling profits by this association from its germination onwards. How what must surely at first have begun as mere parasitism has thus evolved, and to this most intimate of co-operations, thoroughgoing and life-long, as symbiosis, gives us the most vivid of imaginable instances of that "optimism of pathology," of which instances are increasingly appearing for diseases. Such interpretations have been once and again suggested throughout the past, and even in the social world, in its struggle with evils, yet sometimes also with stimulus from them as well. Theologians have indeed thus often taught, and philosophers have thus speculated, before the physicians, as these again before the naturalists; for to them it has long naturally appeared obvious that the race is to the swift and the battle to the strong. But these physicians are setting us thinking anew; and when one of their latest writers on the most terrible of diseases can entitle his volume "Malignancy and Evolution"—and even

with social illustrations as well as physiological interpretations all along—it is no wonder that some of us organic evolutionists are also feeling compelled to question our old fundamentalisms anew, and so to begin searching towards what we may find of "soul of goodness in things evil," as here distilled in nature, even to display over great landscapes.

Our forest guide next takes us along the Sussex Downs, and interprets their varied landscape, as ranging from grass pastures to spreading masses of thorny scrub, amid which sprout ash saplings, by and by growing to trees; yet these again sheltering oaks, in time increasingly to replace them; while the deep and shady beechwood slowly moves on towards conquering all. Thus clearly he brings out for us what neither their old-world shepherds nor woodmen had grasped, nor yet the innumerable painters or even traditional field-botanists who have roamed them. For now these more comprehensive forest-botanists—more like impressionist painters, since no longer concentrated upon foreground details almost alone—are discerning the definite march and succession of these plant-formations in historic order, as above.

The parallelism of such successions of plant-associations to those of colonisations and conquests of regions by man, both historic and contemporary, is here surely too obvious to miss. This human inquiry has long been in progress among historians and politists, but never more than during the past and present generations. So now such plant-association-historians, as their social and historic interests increase, have fine volumes before them, as they go on mapping their own results, and continue comparing them with human changes; as manifested in living survivals or as preserved in the records which archæologist and paleographer are respectively searching anew.

The preceding naturalists and their papers have thus each their varied and instructive suggestiveness towards making out the ways of human life. Yet it is their veteran leader, Prof. Thomson, who has longest meditated and most fully written on these parallelisms of organic and social life, so that he is now probably the very soundest of living critics and expositors of the contributions of biology to the social sciences. Hence his chapter on social animals—with its wealth of illustrations, old and new, and taken from well-

nigh all levels of organic life—thus especially needs and rewards re-reading; and notably for its balanced judgments, both of the communal advantages of social organisation, and of the various limitations to individuals which so often accompany these.

The last contribution—that of Dr. Lockhart, anatomist and anthropologist—despite the still too common impression that his subject, since concerned fundamentally with a few broken skulls, and long-disused flint implements, must be the driest of all our nature-studies—is singularly vivid and graphic, in fact the most glowing of the whole series. For here he vividly recalls the early human past, still so fragmentary, yet which we are nowadays coming to realise and understand better than many a more recent civilisation. His chapter abounds in themes for reflection. Thus, for single instance, in our age of technical advances, and even with notable artistic creations also, it is well for the moderation of our pride of progress, to be reminded of a race finer and astonishingly bigger-brained than any of the subsequent ones from whom we living men are mingled descendants, and in whom the crafts

and even fine arts of the old Stone Age were reaching towards culmination, should yet have vanished: and this to give place to peoples inferior alike in body and brain and in creative arts, but beginning their then new civilisation of agriculture. So when all is said and done for our science, as yet so predominantly physical, and for our industry, so essentially mechanistic, and these together as the bases of our "progress" and its pride, is it not also well for us—as workers and scientists here in council—to be turning to life-studies and life-activities? And these as after all fundamental—and even supreme—for the understanding of our own evolution, organic and social together? And so for the carrying on of these? And in better ways than our predominant industries and sciences have yet been doing?

In further vivid pages Dr. Lockhart gives glimpses of many of the active inquiries current among anthropologists, now so busy in gathering all they can from the strange ways of human life presented by the time-elaborated civilisations they find in all corners of the earth and isles of the sea; yet which were veiled to their predecessors by reason of the long-current "Savagery-

Myth," which is still too hard to dissipate, since so plausibly justifying their destruction. Anthropologists, till not so long ago, were mainly esteemed by each other (too much like Dyak headhunters) in terms of their collections of skulls: yet now all modern ones worthy of the name are learning for themselves what Tylor of Oxford was wont to tell his pupils: "The more you come to know of any people, however seeming simple, or even repellent, the more you will have to respect them—the more you will even come to love them!" In this late-developing sympathy of man for man, we have the newer—and the true—anthropologic spirit: and its extension, amid the varied controversies and parties, strifes and wars of contemporary civilisation, will be the best general contribution that science can bring them.

Yet as our writer (and each predecessor also) rightly claims, this nascent association of natural and social knowledge is forecasting fresh advances and applications. Witness conspicuously the incipient science—and coming art—of eugenics, inspired by our recent renewals of the ancient skills of animal and plant breeding, and now

searching its way towards human betterment.

Our naturalistic and human studies and endeavours have thus long been going on together, though irregularly always, and incompletely still. From going to the ant we are assuredly a bit the wiser; and so too by comparing human breeds with those of lower species. And again in finding that nature has room both for individualistic and socialised life-ways and values, many and various, and even for combinations among these anew. It is too early to be dogmatic; and we have already too often seen hasty generalisations used to project crude panaceas. But the biological sciences, despite their intricacies and complexities, and the psychologic and the social sciences, more complex still, are all advancing; and this not only in their specialisms, but towards synthesis in a better understanding of life, organic and human together. Our little group of writers and readers are here in a movement which is becoming world-wide: so the main service a book like this can render is to encourage others to join them in their quest—that of a science—and even a philosophy—of Life, organic and human; and

thus correspondingly of wisdom, in practical applications and in social development—throughout all regions, all cities; and so uniting in individual and in social evolution workers and thinkers together, and each leading by turns.